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THE SOUTHERLY EXTENSION OF THE ONONDAGA SEA IN THE ALLEGHENY REGION[1]

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It is proposed in this paper to present some of the evidence which calls for a distinct modification of the current conception of the extent of the Onondaga sea in the eastern part of the United States. Before submitting the new data the reader's attention will be invited to certain features of the previously recorded faunal and lithologic facts relating to the Onondaga sediments which, in the writer's opinion, have led to some misconceptions regarding the character and extent of the Onondaga sea in the eastern states.

The Onondaga fauna as developed in the states of New York, Ohio, Indiana, and Kentucky was one of the first of our Paleozoic faunas to be studied and described. The reports of the state surveys of these states, supplemented by numerous unofficial papers in which this fauna has been recorded and illustrated, have made it one of the best known of the Paleozoic faunas. It is a noteworthy fact, however, that all of the various contributions to our knowledge of this fauna have dealt with a nearly pure limestone fauna. If one were to seek a comprehensive idea of the character of the Onondaga sea and its sediments from the published descriptions of the fauna and the limestones holding it, he would get the conception of a sea in which only limestones were deposited. To any-

[1] Published by permission of the Director of the United States Geological Survey.

one who admits that the factors controlling marine sedimentation were essentially the same in Paleozoic and recent times, a Devonian sea in which only calcareous sediments accumulated is a manifest absurdity. We know of no continental or other seas in which there are not a variety of types of sediment accumulating simultaneously. Papers which have undertaken to deal with this fauna in a large way and weld its evidence into the new science of paleogeography have naturally been influenced by the fact that the only faunas described from the Onondaga sea were limestone faunas. Translated into the form of a paleogeographic map this class of evidence taken alone gives us a sea whose outlines inclose only limestone sediments. This was a serious defect in Professor Charles Schuchert's first map of the Onondaga sea.[1] The shorelines given by it for the Onondaga sea in the central states inclosed a sea from 100 to 300 miles in width. All of the known Onondaga deposits included by the shorelines of the map are limestones. The recently published map of the middle Onondaga by Professor Schuchert[2] shows improvement in this respect, since it includes the shales and argillaceous limestone bands holding the Onondaga fauna which was discovered in central Pennsylvania by Charles Butts and determined by the writer. The later map, however, still gives us a conception of the Onondaga sea far from that which the writer's recent studies in the Allegheny region appear to demand. The writer's criticism, it may be stated here, is directed primarily, not to Professor Schuchert's map, which incorporated all of the positive evidence available at the time of its preparation, but at the incompleteness of the evidence in a region where it might be expected to be fairly complete.

In order to ascertain to what extent recorded evidence and opinion will enable us to reconstruct the shorelines of the Onondaga sea within the limits of the eastern states so that they will appear consistent and rational with reference to the character of the known deposits of that sea, we may consider briefly the principal sources

[1] Charles Schuchert, "On the Faunal Provinces of the Middle Devonic of America and the Devonic Coral sub-Provinces of Russia, with Two Paleographic maps," *Am. Geol.* (1903), XXXII, 137–62, Pl. 20.

[2] Charles Schuchert, "Paleogeography of North America," *Bull. Geol. Soc. Am.*, XX (1910), 75.

of its sediments. The comparatively thin mass of sediment which accumulated during the whole of the Devonian in the central states affords satisfactory evidence that the land area adjacent to the Devonian sea on the west had slight relief, and furnished comparatively little sediment at any time during the Devonian. On the east side of the Devonian sea, however, physiographic conditions were very different. Willis[1] has shown that during much of the Devonian period there lay immediately southeast of the Allegheny region the highlands of Appalachia. This old land area furnished to the interior Devonian sea of the Appalachian region, between the beginning of the Hamilton epoch and the close of the Devonian, a mass of sediments which, if restored upon a sea-level plain of Appalachia, "would constitute a mountain range closely resembling in height, extent, and mass the Sierra Nevada of California."[2]

According to the prevailing view[3] this fertile source of Devonian sediments was elevated at the close of the Oriskany to such an extent that throughout Onondaga time the Allegheny region was a land area. Such elevation, if it occurred, must have resulted in accelerated erosion in the Devonian highlands, and in an increased volume of sediments in the Onondaga sea. If this hypothetical uplift occurred, it could not have failed to have been registered by a great thickness of coarse clastic sediments in the narrow Onondaga sea which, as outlined by Schuchert's map, extended as a narrow belt across the adjacent portions of the present states of Kentucky, Indiana, and Ohio. Instead of such coarse clastics we find in these states, as previously noted, only limestones representing sedimentation near the eastern shore of the Onondaga sea as outlined by Schuchert.[4] The utter impossibility of harmonizing the pure limestone deposits representing the Onondaga in the Ohio valley with this currently accepted theory of diastrophism in the Allegheny region would appear to be a sufficient reason for discarding it. If, however, we assume that Appa-

[1] *Md. Geol. Survey, Special Publication*, Vol. IV, Pt. I, pp. 61–62.

[2] *Ibid.*, p. 62.

[3] Charles Schuchert, "Paleogeography of North America," *Bull. Geol. Soc. Am.*, XX (1910), 492.

[4] *Ibid.*, Pl. 75.

lachia was not elevated and the Devonian shoreline was not pushed westward at the initiation of Onondaga time, we would still expect as a probability non-calcareous sediments to predominate in the eastern portion of the Onondaga sea. That portion of the Onondaga sea adjacent to the land area which furnished 10,000 feet of non-calcareous Devonian sediments in post-Onondaga time would be likely to acquire chiefly non-calcareous sediments even in an epoch so favorable to calcareous sedimentation as the Onondaga.

A considerable mass of paleontologic and stratigraphic data which has been gathered by the writer shows that Onondaga sediments are present in the Allegheny region and are mainly of this non-calcareous type, as might have been expected from theoretical considerations. The recent discovery of an Onondaga fauna in the Allegheny region which occurs in a series of drab or dark shales and thin interbedded argillaceous limestones thus very materially supplements the hitherto one-sided character of the available data relating to the nature of the fauna and sediments of the Onondaga sea. The sediments holding this fauna are of such a character as we might have expected to be accumulating on some portion of the Onondaga sea floor if we may judge by analogy with the processes of sedimentation now in operation in the largest continental seas. Since this fauna will be described and figured in a forthcoming bulletin of the United States Geological Survey, only the most general facts regarding it will be presented here. The fauna comprises more than one hundred species. The correlation of this Allegheny fauna with the New York Onondaga fauna is based primarily upon the presence in it of such well-known species as *Anoplotheca acutiplicata*, *Rhipidomella vanuxemi*, *Spirifer acuminatus*, and *Odontocephalus aegeria*. The great abundance and general distribution of the first named of these species is a conspicuous characteristic of the fauna. In point of abundance and wide distribution in this argillaceous facies of the Onondaga, *Anoplotheca acutiplicata* is as prominent as is *Spirifer acuminatus* in the well-known calcareous facies. It is interesting to note in this connection that while *Anoplotheca acutiplicata* is a familiar species in the Onondaga limestone of eastern New York comparatively near the region under discussion, it is unknown in the more westerly areas

of the limestones of Onondaga age in Ohio, Indiana, and Illinois. Its occurrence in typical Onondaga limestone only in an area which is nearly adjacent to the region of the shaly facies of the formation suggests that the latter type of sediments furnished its normal and most congenial habitat. *Spirifer acuminatus*, on the other hand, does not extend very far to the southward into the region occupied by the argillaceous facies of the Onondaga. Other Onondaga species, however, like *Odontocephalus aegeria*, appear to be equally adapted and distributed in both types of sediment.

Some of the stratigraphic data relating to this fauna may be very briefly summarized as follows:

The calcareous shales holding this fauna are generally preceded in the sections by the Oriskany sandstone and always followed by the dark fissile and comparatively barren shales of the Marcellus. These two limiting formations exhibit in general essentially the same lithologic characters throughout Pennsylvania, Maryland, West Virginia, and much of Virginia as in New York. Both are, however, much thicker in this more southerly region than in the type region of the Onondaga limestone in New York. In the Helderberg mountain region the Onondaga and the Hamilton faunas are separated by 300 feet of comparatively barren dark Marcellus shale, and in western New York by about half this thickness, while in Pennsylvania and southward these shales often have a thickness of more than 500 feet.

While the succession from the Onondaga fauna to the Marcellus fauna above is a uniform one throughout most of the Allegheny region, as it is in New York, the succession at the base of the fauna is not everywhere precisely the same. In most of the territory the Onondaga beds rest upon the Oriskany, but in some of the Pennsylvania sections they immediately follow beds representing the Esopus shale. In respect to its underlying formation, however, the Onondaga shows less variation than in New York, where, in different areas, it is found to follow the Manlius, Oriskany, Esopus, and Schoharie. Thus, we find that this fauna occupies in the Allegheny region the same relative position in the succession of faunas as the Onondaga fauna does in the standard sections of New York. The stratigraphic evidence, therefore, coincides with the paleontologic

evidence already briefly cited in pointing to the Onondaga age of the fauna. We may now consider the bearing of the data which have been cited on the modification of the current conception of the eastern shoreline of the Onondaga sea in the eastern United States.

The Onondaga formation extends scarcely south of the Delaware River according to most of the papers dealing with the stratigraphy of the Devonian in the Allegheny region, thus giving it a north-south extension of scarcely 200 miles. This comparatively insignificant southerly extension of a fauna which is so persistent in a westerly direction seems more surprising when it is recalled that all of the other faunas characterizing the major divisions of the New York Devonian section have with one or two exceptions been traced southward from New York entirely across Pennsylvania. Thus it is seen that the prevailing conception of the Onondaga formation and fauna, which presumes their absence south of New York, gives to it an anomalous position as compared with the other important formations of the Devonian section of New York. The evidence which the writer has gathered during three seasons of field work in the Allegheny region indicates that the southerly extension of the Onondaga fauna is quite comparable in distance with its westerly extension. The field studies of the writer have shown that the Onondaga fauna in the Allegheny region extends far to the southward of the area in which nearly pure limestones were deposited during Onondaga time into a region where shale-forming sediments partially or completely dominated those of calcareous type. This fauna has been found in nearly all the sections studied from New York to Tennessee.

The direct bearing of these new data on the paleogeography of Onondaga time is obvious. Its incorporation involves the extension of the eastern shoreline of the Onondaga sea in a southwesterly direction from southeastern New York to the eastward of the Allegheny region instead of far to the westward of it, as now drawn, across the states of Ohio, Indiana, and Kentucky. In the light of this new evidence it appears that the eastern shoreline of the Onondaga sea trended southwesterly across north-central New Jersey and southeastern Pennsylvania. It probably traversed the

states of Maryland and Virginia near the present axis of the Blue Ridge Mountains. From southwestern Virginia this shoreline appears to have trended westerly not far from the Kentucky-Tennessee line as far as the valley of the Tennessee River where it resumed its southerly trend. This revision of the shorelines of the Onondaga sea gives, instead of the Cincinnati peninsula of Schuchert's map, a Cincinnati island. This, and probably other smaller islands, interrupted the continuity of the Onondaga sea, which, in the region of the Ohio valley, reached a maximum width of about 500 miles from northwest to southeast.

THE MISSISSIPPIAN–PENNSYLVANIAN UNCONFORMITY AND THE SHARON CONGLOMERATE[1]

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There exists in northern Ohio a well-defined boundary between the strata of the Mississippian and Pennsylvanian ages, a boundary marked by a pronounced unconformity. The upper limit of the Mississippian is the top of the well-known Cuyahoga formation, and the lower limit of the Pennsylvanian is the bottom of the equally well-known Sharon conglomerate.

So far as the writer is aware the Sharon has been generally regarded as a formation of general extent around the northern and northwestern border of the Appalachian coal basin, and resting upon the Mississippian in a continuous sheet except where removed by erosion.

Field work the past summer in Mahoning, Trumbull, Portage, Summit, and Geauga counties has revealed some facts that lead the writer to believe that the Sharon conglomerate is not the simple formation that it has been thought to be, and that it has a setting of unusual interest.

Following its outcrop from place to place, the formation is found to change in structure quickly, to disappear suddenly, and to be absent over considerable areas, letting later rocks form the contact with the Cuyahoga. Where its development is greatest, it lies in troughs of the Cuyahoga. Further, it is found to occur in belts having a more or less north-and-south direction, and these belts, in places at least, are not now and never have been connected from east to west. This is due, in part at least, to the fact that the conglomerate lies between ridges of the Cuyahoga, and not alone to post-Pennsylvanian erosion.

[1] Published by permission of Dr. J. A. Bownocker, state geologist of Ohio. Presented at the twentieth meeting of the Ohio Academy of Science, Akron, November 25, 1910.

This manner of occurrence calls attention to the surface upon which the Pennsylvanian rests. Whatever may be the case elsewhere, the writer believes that greater erosion of the upper Mississippian occurred in northern Ohio than is generally known. Instead of the Sharon resting upon a nearly uniform plane, it is found that the surface of the Cuyahoga has a relief of nearly 200 feet, and it is significant that where the depressions are greatest, the Sharon is also thickest. The regional or belt-like occurrence of the conglomerate, and its apparent relationship to depressions in the Cuyahoga, along with the structure and variability of the stratum, have led the writer to the conclusion that these depressions are creek and river valleys, and that the conglomerate is a deposit of stream gravels, and that the overlying sandstones of the Pottsville are, to a greater or less extent, river and delta deposits.

Some of the data on which this view is based are added. Valleys in the Cuyahoga formation are of general occurrence. The most conspicuous and deepest one so far found may be noted in some detail. This valley lies in the eastern edge of Portage and Geauga counties, about half-way between Akron and the state line, and its course is roughly north and south. At Akron, the top of the Cuyahoga formation lies about 940 above sea; due east, at Mineral Ridge, west of Youngstown, at 962; at Newton Falls, between these two points, and 5 miles north of the Akron-Mineral Ridge line, it lies below 850, or about 100 feet lower than to the east or west. If such a line be drawn from east to west half-way between Akron and Cleveland, the same depression in the Cuyahoga is again found. At Brandywine Falls, 15 miles north of Akron, the top of the Cuyahoga formation lies at 1,040; near Howland Springs, due east of Brandywine, at 1,044; and at Nelson Ledges between these two points at 956, or again nearly 100 feet lower.

Another east and west comparison may be cited. At Burton, due east of Cleveland, the top of the Cuyahoga lies at 1,090 and due east on the state line at 1,190, or 100 feet higher. These three middle points—Newton Falls, Nelson Ledges, and Burton—are in line, roughly, north and south, and are clearly in a depression of the Cuyahoga formation, since rock of this formation lies higher both to the east and west. Further, this depression cannot be

assigned to a syncline, as is proven by the nearly horizontal position of the Berea in the same direction. It is worthy of note that the Sharon and overlying sandstones in the line of this old valley reach their greatest development in Ohio, and form a great body of conglomerate and sandrock extending southward from southern Lake County, through Geauga and Portage counties, at least as far south as northern Stark County. The evidence is strong that the conglomerate and overlying sandstones in this great ridge are stream deposits, and will be discussed later.

It may be objected that the distances involved in the three lines across this supposed valley are of such length as to be of doubtful value. Data are at hand, however, which confirm fully what the three lines of elevation show. At Brandywine the Sharon base is 210 feet above the Berea; due east at Nelson Ledges only about 75 feet; near Newton Falls only about 75 feet; but on the state-line nearly due east of Nelson Ledges nearly 300. The meaning of these figures is clear, and shows deep erosion, which is still further confirmed by the presence of hills of the Cuyahoga in the very region in which the erosion was greatest. As stated above, the top of the Cuyahoga near Newton Falls lies below 850 and in $2\frac{1}{4}$ miles north rises to 1,040 above sea-level. It therefore forms a hill at least 190 feet high, with no trace of the Sharon or overlying sandstones. Within $3\frac{1}{2}$ miles to the northwest from this hill, and in a direction opposed to the dip, the surface sinks to 919 feet at least. At Nelson Ledges the conglomerate is about 75 feet thick, and one solid mass from bottom to top. It appears to the observer that it may be expected to continue for miles to the north, but instead it thins out quickly on the steep slope of another Cuyahoga hill, which rises from 956, at the base of the Ledge, to 1,107, a rise of 151 feet in 1 mile. Within 2 miles to the northwest from this hill, the surface drops again to 990, or 117 feet, as seen in the Parkman gorge. From this point the surface rises again to the northeast, 180 feet in $2\frac{1}{2}$ miles, then falls toward the northwest. At Newton Falls, there is a like rise toward the northeast from below 850 to 941, in about 3 miles. Now all points which show these old hills are on or near the eastern margin of this rock ridge, and in every case

bear evidence of a more or less westerly slope toward the ridge. They are clearly hills bordering a valley, and are conclusive evidence of former dissection to a depth of nearly 200 feet. This same hill and valley topography of the Cuyahoga is found all through eastern Trumbull and northern Mahoning counties, with the conglomerate often absent, and with the Sharon coal lying close above the Cuyahoga.

One of the finest exposures of the unconformity occurs in Mineral Ridge, south of Niles, and near the Mahoning-Trumbull line. A deep east-and-west ravine cuts through a north-and-south Cuyahoga ridge finely exposing the contact, showing the horizontal shale and flaggy layers of the Cuyahoga, overlain by the steeply inclined strata of the Pennsylvanian. The slope of the Cuyahoga is toward the east, and at an angle of about 25°, is ragged or stair-step like, and is directly overlain by 2 or 3 feet of crude, mixed sandstone, without lamination or bedding planes, which grades quickly into a bluish shale, then to a carbonaceous shale which carries the well-known and formerly much-worked bed of iron ore. The ore is a highly ferruginous limestone, which is certainly the Lowellville limestone. Directly above the ore is a bed of coal—the Mineral Ridge coal—which lies only 8 feet above the Cuyahoga. The sandstone, shale, ore, and coal all lie at the same steep angle above the Cuyahoga.

I have stated above that the Sharon conglomerate bears evidence of being a stream deposit. This appears from its position, its constitution, and its structure. In some places it is little else than a mass of quartz pebbles which range in size from coarse sand to half the size of the fist. Commonly the stratum is an alternation of sand beds and pebble layers, of constant variation both horizontally and vertically. Bottom-set, fore-set, and top-set beds are common. The sudden change from sand to gravel, and the very variable structure of the sand beds, all of which may be repeated several times in a single rock face, can be accounted for only by stream action. There is not any feature of the conglomerate that stream action does not produce. On the other hand, the writer is unable to conceive of any other agency capable of producing a like stratum.

It will be interesting to note the most exaggerated conglomeratic development found. It occurs at the base of the Sharon as exposed in the gorge at the village of Parkman, Geauga County. Lying directly upon the Cuyahoga, and representing a stream velocity of probably 3 miles an hour, is a 3-foot bed composed not of pebbles alone, but of cobble stones, or pieces of flagstone from the Cuyahoga, some angular, some rounded and flat and well worn, 2 to 3 inches thick and more than a foot in diameter, standing and lying in all positions and mixed with sand and pebbles. It is a veritable picture of the stones and gravel and sand all mixed that we have all seen many times on the inside curve of streams. A more convincing evidence of stream deposit in former ages can hardly be found.

It is worthy of note here that two distinct stages in the deposition of the Sharon are displayed in this gorge. At 10 or 12 feet above the base the conglomeratic character is entirely absent, a rather fine soft sandstone occurs, the top of which is quite undulating, as if eroded. Resting directly upon the undulating surface, with a sharp line, is the massive conglomeratic rock characteristic of the Sharon. The transition is sudden and very conspicuous and is well shown at a number of points in the gorge.

At Nelson Ledges the base of the conglomerate lies at 956, and ½ mile west conglomerate is found at 1,160 above sea. This whole thickness of 204 feet is not to be assigned to the Sharon, however. Overlying sandstones are conglomeratic in this locality and sufficiently so to be mistaken easily for the Sharon itself. Two miles south of this point and about ¾ mile south of Nelson village at Ledge Haven Mill conglomerate rock is found on Tinker Creek. There are clearly two stages of conglomerate formation here. The bed of the creek below the fall is conglomerate of unknown thickness. It is directly overlain by 5 to 6 feet of dark gray sandy shale and this is overlain in turn by 30 to 40 feet of conglomerate. The top of the lower stratum lies at 952, as seen at the foot of the fall beside the mill. The shale stratum is strongly suggestive of the horizon of the Sharon coal. It also strongly suggests relationship to the two-stage phase of the conglomerate observed in the Parkman gorge. At the latter place this transition occurs at a level of about

1,000 feet above sea, and is nearly 5 miles north of the above mill, and when dip is taken into account the probability is very strong that the phenomena seen at the two places belong to the same horizon.

A quite singular feature occurs in this shale at the fall. Near its middle, and imbedded in it, lies a lenticular mass of conglomerate a foot thick and probably weighing nearly a ton. It contains large quartz pebbles, much pyrites of iron, and an impression of a calamite. How was it transported to this place where only fine sediments were being deposited? Where did it come from, and from what rock formation was it detached? For the conglomerate beneath must have been only a stratum of sand and gravel when it was deposited. In central Ohio three other formations intervene between the Cuyahoga and the base of the Pennsylvanian, the lower one of which—the Black Hand—is known to be conglomeratic in part. Is this conglomerate block imbedded in this shale a remnant of the Black Hand which once may have overlain the Cuyahoga in northern Ohio, and was completely removed by erosion before the close of the Mississippian? These are questions to which only further study may reveal the answer.

THE WICHITA FORMATION OF NORTHERN TEXAS[1]

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With discussions of the Fauna and Flora by
GEORGE H. GIRTY AND DAVID WHITE

INTRODUCTION

The geology of the "Red Beds" area of northern Texas has long been recognized as one of the perplexing problems of North American geology. The interest aroused by the discovery in these beds of a fauna which was regarded by Cope, C. A. White, and others as Permian has brought forth a number of papers bearing on this region, most of which are based on transient visits in search of fossils, generally with scant attention to the detail of stratigraphy.

This paper is based upon investigations made in connection with the study of underground water conditions for the United States Geological Survey during the field seasons of 1906 and 1907. The collections of invertebrate fossils made in the course of the investigations were submitted to Dr. George H. Girty of the Survey, who also had for study additional materials collected by E. O. Ulrich in former years.

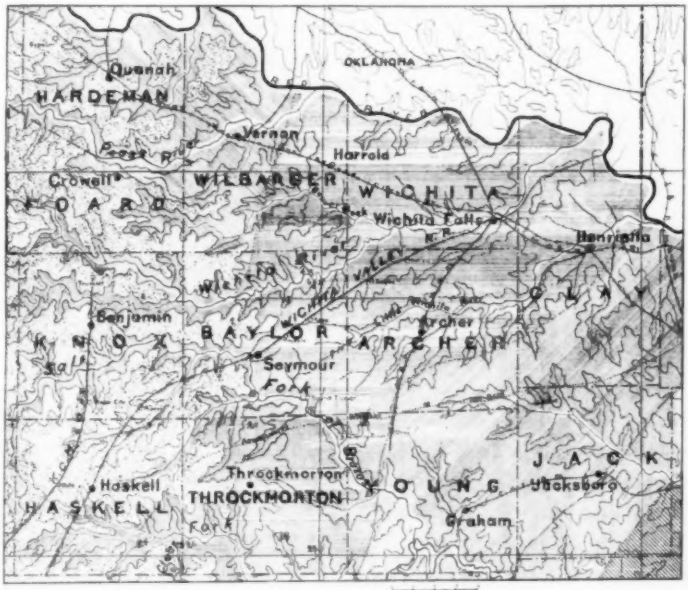
STRATIGRAPHY OF THE REGION

The "Red Beds" area.—The area occupied by the "Red Beds" in northwestern Texas is bounded on the west by the eastern escarpment of the Llano Estacado, and extends eastward along the Red River to Montague County, where the formations pass from sight beneath the basal beds of the Cretaceous. From this point the eastern boundary of the "Red Beds" bears south and then westward, following approximately the lines between Jack and Clay, and Young and Archer counties as far west as the Salt Fork of the Brazos. From this point it bears southwestward to the south-

[1] Published by permission of the Director of the United States Geological Survey.

eastern corner of Haskell County, thence irregularly south until it meets the Cretaceous again in Concho County.

As thus outlined, the "Red Beds" occupy an area of irregular shape 80 to 100 miles in width in the southern portion, while at



the north they extend eastward fully twice that distance along the south side of Red River. If a line be drawn from a point on Red River near the mouth of Pease River southwestward through Seymour to the northeastern corner of Haskell County and thence southward, it will mark approximately the eastern boundary of a series of red clays and red sandy shales containing gypsum in varying amounts, to which the names Clear Fork and Double Mountain

were applied by Cummins in reports of the Texas Geological Survey. These are evidently the equivalents of the beds included by Gould[1] in the formations to which he applied the names Greer and Quartermaster. As these beds have no connection with the problem in hand, they may be dismissed from further consideration. It is to that portion of the "Red Beds" area adjoining the Red River and extending eastward from the line above indicated that most of the discussions concerning the Texas Permian apply. This is the type area of the Wichita formation of Texas. The western part of this area is characterized by the occurrence of beds of limestone and blue shale interbedded with red clays and sandstones, while the eastern part is notable for the entire absence of limestones and the very limited development of blue shale and clay. If a line be drawn from a point where the Salt Fork of the Brazos crosses the boundary between Throckmorton and Young counties, a little east of north to Red River, it will mark approximately the boundary between the areas thus lithologically distinguished. According to Cummins' earlier writings[2] most of the rocks of this western area were assigned to the Clear Fork formation, while the strata occurring toward the east constitute his original Wichita division. Many of the fossils on which his conclusions regarding the Permian age of the beds were based, however, appear to have come from the basal portion of the limestone series in eastern Baylor County.

In the earlier reports the Wichita formation is described as having no surface development south of the point where the "Red Beds" boundary meets the South Fork of the Brazos River in the northeastern corner of Throckmorton County. From that point southward the Clear Fork formation is said to rest directly upon the "Albany," considered to be the highest division of the "Coal Measures" in that region. This peculiar relation of the Wichita formation was conceived to be due to overlap, and hence it was believed that an unconformity marked the relations of these beds to the "Coal Measures." In a later paper,[3] read before the Texas

[1] Charles N. Gould, *Water-Supply and Irrigation Paper No. 191* (1907), 14–19.

[2] *Geological Survey of Texas*, II (1890), 401. See map facing p. 552.

[3] W. C. Cummins, *Transactions of the Texas Academy of Science* (1897), II, 93–97.

Academy of Science, Cummins announced the discovery of evidence showing that the limestones of eastern Baylor County are the same as those of the "Albany." In this paper the beds of Baylor County are said to constitute the upper part of the Wichita. Owing to the discontinuance of the Texas Survey the report on this area prepared for the *Fifth Annual Report* has not appeared.

Rocks of the Wichita area.—East of Baylor County the rocks consist for the most part of red concretionary clays, red sandstones and sandy shales with occasional beds of blue shales, and bluish to grayish-white sandstones. Limestones are conspicuously absent. Occasional impure nodular layers occur, however, which contain considerable calcareous matter, but these do not constitute strata of limestone. The sandstones are usually soft and distinctly cross-bedded. In some places they are shaly, in others massive. Some layers are streaked and specked with grains of black iron oxide, while others contain nodular masses and concretions of iron ore.

The clays are mostly deep red or red mottled with bluish-white and drab colors. The red clays contain an abundance of nodular concretions of irregular shape varying in size from that of a pea to masses 4 or 5 inches in diameter. They consist of clay, iron, and lime, and at times are hollow or with the interior filled with calcareous clay or lime carbonate. In some cases they are flattened and stand in vertical position in the clays, suggesting their origin through the filling of fissures.

Occasionally a bed is met with consisting of rounded lumps of hardened clay cemented together by ferruginous matter, representing what Cummins called "a peculiar conglomerate." This formation is believed to have had its origin in the breaking-up of a bed of clay by running water or wave action.

In places the bluish clays are copper bearing. Efforts to mine these deposits, however, have not been profitable. The ore occurs in the form of small nodules in the clays and also as a replacement of wood.[1]

In the sandstones occasional traces of plants occur, and sometimes remains capable of identification are found. White reports *Taeniopteris* from the sandstones near Fulda. The stratification

[1] J. F. Cummins, *First Annual Report, Geological Survey* (Texas, 1889), 188–96.

of the beds is very irregular. The sandstones, shales, and clays grade into each other both vertically and horizontally. Moreover there is a monotonous similarity in the sandstones and shales respectively throughout the area, which, taken in connection with the absence of any persistent easily recognizable stratum, renders the stratigraphic correlation of the beds, except within very narrow limits, practically impossible.

In eastern Clay and Montague counties, the beds, considered Cisco, show a greater development of sandstones some of which are conglomeratic. In the western part of the area, however, no true conglomerates were observed.

As to the thickness of the Wichita, no definite statement can be made. Certain of the beds may be traced for a limited distance sufficient to indicate a general westward dipping of the strata. Cummins estimates it to be 35 feet per mile, which is probably too high. The width of the outcrop in an east-west direction is about 50 miles, which, assuming a regular inclination of 25 feet per mile, would give a thickness of 1,250 feet for the beds outcropping in this portion of the field. How much of this should be referred to the Cisco is conjectural, but probably not less than half. A well put down for oil at Electra, which is located near the top of the formation, passes through 1,790 feet of red clays with some sandstone and red sandy shales. At Petrolia, which is near the middle of the outcrop, the oil wells are for the most part about 400 feet deep, chiefly in red clays and shales. Drilling has extended to a depth of 800 feet in some instances and indicates an increase in the proportion of blue shales below, but no reliable record could be obtained of the lower formations passed through.

At Archer City a well 737 feet deep shows red clays and reddish sandstones predominating to a depth of 670 feet. Below this the drill revealed similar deposits but in diminished proportion, as compared with the light-colored sands and bluish clays. Since the upper beds of the Cisco in this region are prevailingly red, however, no reliable conclusion can be drawn from well records as to the plane of division between the formations.

In the bluffs of the Wichita River in the northwestern corner of Archer County some beds of limestones aggregating 4 feet in

thickness appear at the top of the escarpment on the west side of Horseshoe Lake, and outcrops of these appear at intervals along the boundary of Archer and Baylor counties. This limestone is earthy, very hard, dark blue where fresh, and weathers to dark brown or black. It is underlain by 4 feet of blue clay. The remainder of the section to the base of the hill, about 100 feet, consists of red concretion-bearing clays with a limited development of red and white shaly sandstone. From this point westward the stratification becomes more regular, consisting of the blue shales alternating with the red, the red being predominant, with an occasional bed of dark earthy limestone containing usually an abundance of poorly preserved fossils.

At the Bar-X ranch on the Wichita River in the northeast corner of Baylor County near the Old Military Crossing, several ledges of hard limestone appear in the river bluffs separated by varying thicknesses of blue shale, alternating with red clay. The beds dip to the westward at inclinations estimated at 20 to 30 feet per mile. Proceeding up the river from this point, limestones appear at intervals in increasing development, the best outcrops occurring about 2 miles east of where the Seymour-Vernon road crosses the river. Here an escarpment 90 feet in height has the lower two-thirds composed of red and blue shales alternating with beds of limestone. The middle of the section consists of red and concretionary clays and sandstones. Some of the ledges of limestone are massive, but others are thin-bedded and shaly, and separated by varying thicknesses of bluish clay. Locally the thin-bedded limestones and their included shale grade horizontally into more massively bedded limestones. Fossils are not plentiful in this locality. The same beds are exposed again northward in the banks of Beaver Creek. At Seymour the limestones are well exposed in the banks of the river where they are quarried to some extent and furnish a stone that is well adapted to ordinary uses. The beds are here transected by the Salt Fork of the Brazos River, which flows in a relatively narrow valley between steep bluffs 200 feet high, made up of interbedded red and blue clays, and limestones.

The limestones of Baylor County area are generally fossil-

iferous. Owing to the hardness of the rock, however, good specimens are difficult to obtain. Toward the south there is an increase in the development of blue shale and limestone, while the red clays and sand show a corresponding diminution. In a recent paper[1] Case has endeavored to correlate certain of the sandstones occurring throughout the area, one of which he calls Fulda, from a little station by that name in eastern Baylor County. With this sandstone he correlates others which outcrop as far east as Wichita Falls, a distance of 37 miles. With this conclusion the writer is not in accord. In the first place, the sandstones at Fulda are underlain by some thin limestones which outcrop toward the northeast in the northwestern part of Archer County. It is quite apparent that the sandstones in eastern Archer and Wichita counties represent horizons below these limestone beds. Assuming the general westward dip of the strata to be no more than 20 to 25 feet per mile, there must be a descent of not less than 650 to 800 feet to which must be added the rise of the plateau surface which is about 200 feet, making a total of 850 to 1,000 feet between the horizon represented at Wichita Falls and that at Fulda and rendering untenable the correlations suggested.

Albany area.—The eastern boundary of the Clear Fork and Double Mountain formation in eastern Jones County is marked approximately by the Clear Fork River. The region to the east of this point to the limits of the Cretaceous in western Parker and Wise counties, a distance of over 100 miles, known as the Brazos Coal Field, is occupied by rocks of Carboniferous age. These beds, which have a thickness of nearly 7,000 feet, present lithological, stratigraphic, and faunal characteristics, which permit their separation into four well-marked divisions, known as the Strawn, Canyon, Cisco, and "Albany" divisions.[2] Southward in the Colorado Coal Field the equivalent rocks were first studied by Tarr,[3] who

[1] E. C. Case, *Bulletin of the American Museum of Natural History*, XXIII (1907), 659–664.

[2] These names appear first in the *First Annual Report of the Geological Survey of Texas* in the State Geologist's "Report of Progress," pp. lxv–lxvii. Hill, however, credits them to Cummins (*Twenty-first Annual Report, U.S. Geological Survey*, Part VII, 97).

[3] R. S. Tarr, *First Annual Report of the Geological Survey of Texas* (1889), 201–16.

subdivided them into five divisions as follows: Richland, Milburn, Brownwood, Waldrip, and Coleman. Later the Milburn was included in the Brownwood.[1] The relations of these rocks as now recognized are as follows:[2]

Colorado Field (Tarr)		Brazos Field (Cummins)	Thicknesses in Feet
Coleman		"Albany"	1,200
Waldrip		Cisco	800
Brownwood Milburn	Brownwood	Canyon	800
Richland		Strawn	4,100

The beds dip to the west at a low inclination estimated by Cummins to be 30 feet per mile for the "Albany" and 75 for the Canyon.

Limestones constitute the dominant characteristics of the "Albany" and Canyon formations, while sandy shales and sandstones, with some conglomerates, make up the larger part of the Strawn and Cisco formations. It is with the two uppermost of these, the "Albany" and Cisco, that the "Red Beds" problem is concerned.

The "Albany."—The "Albany," named from the county seat of Shackelford County, consists of blue, gray, and yellowish limestones, alternating with beds of blue and dark-gray shales. The upper 500 feet are characterized by massive beds of hard blue limestone, with partings of blue shale, while the lower portion shows a greater development of shale, the limestone being for the most part thin-bedded and shaly. The heavy ledges of limestone appear at the surface in a succession of terraces which extend in sinuous curves from north to south. Sandstones and conglomerates are almost entirely lacking. The formation contains an abundant marine fauna, which, taken in connection with the notable development of limestones, indicates deep seas and quiet conditions of deposition. Above, the formation grades rather abruptly into red gypsiferous clays and red sandy shales and sandstones. The base of

[1] R. T. Hill, *Twenty-first Annual Report of the U.S. Geological Survey*, Part VII (1899, 1900), 98.

[2] The thicknesses cited are those given by Drake, "Report of the Colorado Coal Field of Texas," *Fourth Annual Report, Texas Geological Survey* (1892), 371–446.

the formation is placed just below the main limestone and the blue shale series, the line marking the boundary with the Cisco coinciding approximately with the east line of Shackelford County.

The Cisco.—Below the "Albany," and outcropping to the east of that formation, is the Cisco, which is composed of sandstones and shales, with some conglomerates and two or three beds of coal. Occasional beds of limestones occur in the lower part of the formation and again near the top. Coal outcrops along the Salt Fork of the Brazos River west of Graham in Young County, and elsewhere to the northeast and southwest. Some of the beds of coal are associated with limestones, in one case a thickness of two or three feet of limestone resting directly upon a bed of coal. The conglomerates consist of sub-angular fragments of flinty blue limestone and chert cemented together by a ferruginous sand. Nodules and hollow concretions of limonitic iron ore are common. These conglomerates have been recognized at two different horizons and in widely separated localities. Their exact relations, however, have not been clearly defined. In Stevens County the clays are mostly blue and yellow. Limestones appear at intervals, but these thin out northward, while the clays show a corresponding increase in development.

Relation of the "Albany" to the Wichita.—When traced northward, the limestones of both the "Albany" and Cisco formations diminish in thickness, while there is a corresponding increase in the intervening beds of shale. In the case of the "Albany" the limestones show also a change, becoming more earthy and irregular in their texture, and some of the beds passing into gray indurated clays. The few limestones in the upper part of the Cisco formation disappear entirely in the northern part of Young County. Along with this change there is an increasing development of red clay, alternating with the blue. The massive beds of limestones constituting the upper part of the "Albany" along the Clear Fork in northwestern Shackelford County and in western Throckmorton County were traced northward as far as Beaver Creek in eastern Wilbarger County. They appear in more or less continuous exposures as far north as Seymour, north of which they are covered, but are again exposed, greatly diminished in thickness on Big

Wichita River and Beaver Creek in the line of their strike northward. Greater difficulty is encountered in the effort to trace the lower beds of the "Albany," owing to the greater proportions of clays and sands and the disturbed condition of sedimentation, both conditions becoming more pronounced as the beds are followed northward. Certain of the limestone beds, however, are persistent, although showing changes in their physical character, and by means of these the eastern boundary of the formation was ascertained with a fair degree of accuracy. At Fane Mountain, a low elevation in the southeastern corner of Throckmorton County, is an outcropping of limestone characterized by an abundance of *Myalina permiana*. These beds occur at intervals northward in eastern Throckmorton County, and at Spring Creek in the northwestern corner of Young County they outcrop in the bank of the river about a mile from the post-office. Here the beds show locally a gradation into sandstone suggesting near-shore conditions of sedimentation. On Godwin's Creek, in the western part of Archer County, the diminished representatives of these, or possibly somewhat higher, beds appear, as also farther north on the Big Wichita River. The limestone which outcrops on the Big Wichita north of Fulda, referred to on p. 116, is evidently one of the lowermost beds. The most northerly appearance of presumably the equivalents of these beds was noted in the vicinity of Electra in the western part of Wichita County, where occasional plates of limestone appear over the surface apparently as a result of the weathering out of lenses of limestone in the clays. In the case of the Cisco formation the changes which these undergo toward the North have not had careful study. The limestone, however, appears to thin out entirely in the northern part of Young County, there being no representatives of these formations in the "Red Beds" area except it be the impure, calcareous nodular beds described above.

Nowhere in the southern area so far as observed are there any indications of unconformity. Notwithstanding the lithological and faunal characteristics which distinguish the "Albany," these beds appear perfectly conformable with the Cisco below and the Clear Fork above, nor is there within the formation any indication of stratigraphic discordance. The change in the lithological character

of the beds toward the north is evidently the result of differences in the conditions of sedimentation. The character of this part of the formation suggests very strongly its origin on a coastal plain, or river delta, to the south and west of which lay the sea in which were deposited the marine "Albany" sediments. The interrelations of the two kinds of sediments suggest oscillation of the shoreline upon a relatively wide coastal plain. These changes may be explained as the result of oscillation of the land surface or, possibly better, by the slow but intermittent sinking of the coastal region.

As suggested by Case,[1] Beede,[2] and others, the materials of the "Red Beds" were evidently derived from a land mass on the north, of which the Wichita and Arbuckle mountains are the remnants. The following quotation from Beede's paper is especially pertinent:

> The Arbuckle and Wichita mountains are probably the source of much of the red sediment in which they are partially buried, and the former mountains are directly responsible for the eastern extension of these beds in central Oklahoma. The extent to which the lighter colored sediments of Kansas and Texas are replaced by red sediments in Oklahoma and near it represents in a rough way the limits of the influence of these mountains on the deposits of the time by the spread of their sediments. By the time the deposition of the light colored sediments had ceased the conditions had become such that nearly all the sediments derived from the land surrounding the basin were red.

FAUNAL RELATIONS

In the course of the field work collections of fossils were made at many localities, chiefly in the region occupied by the "Albany" beds. At the close of this paper is given a list of the invertebrate fossils obtained from the Albany and Wichita areas. The list includes the collection made by the author, and those made several years since by Mr. E. O. Ulrich. The localities are indicated on the map by corresponding numbers. These remains indicate, according to Dr. Girty, a marked identity in the invertebrate faunas of the Albany and Wichita areas. In the collections several different faunas can be discriminated. One of these has the brachiopod

[1] E. C. Case, *Bulletin of the American Museum of Natural History*, XXIII (1907), 659–64.

[2] J. W. Beede, *Journal of Geology*, XVII (1909), 714.

element fairly well represented, *Derbya cymbula* being generally present, and the pelecypod *Myalina deltoidea* rather abundant. Another contrasting fauna has, as a rule, brachiopods absent or greatly diminished, but is plentifully supplied with large nautiloids. The faunas appear to have been contemporaneous, both occurring throughout the formation, but in different localities. The nautiloid facies, however, is more prominent in the upper series of beds.

The invertebrate remains of this region were studied by C. A. White,[1] who considered them to be Permian. A map on which the localities were shown was prepared for the *Fifth Annual Report* of the Texas Geological Survey, but never published.[2]

The collections of vertebrates, which in past years have attracted so much attention, were made in the adjoining portions of Baylor and Archer counties. Cope, who first studied them, considered them to be of Permian age. A description of the localities where these remains were discovered has only recently appeared in print.[3] From this description, which is not accompanied by a map, it appears that no fossils were obtained east of the middle of Archer County. In late years interest in the vertebrate remains of the Wichita formation has been renewed and much new material has been obtained, more particularly through the labors of Williston and Case. The results of their investigations have appeared in various papers.

The plant remains from this region have been studied by Fontaine and White[4] and by David White. The last named spent several days in the field in 1909 and collected considerable material from two near-by localities, one, two and one-half miles south of Fulda, and the other four miles southeast of that place. As provisionally identified this material is as follows:[5]

[1] C. A. White, *U. S. Geological Survey Bulletin* 77 (1891).

[2] *Transactions of the Texas Academy of Science* (1897), 95.

[3] W. C. Cummins, *Journal of Geology*, XVI (1908), 737–45.

[4] I. C. White, *Bulletin of the Geological Society of America*, III (1892), 217–18. Study based on identifications by W. N. Fontaine.

[5] No. 1: Cassil Hollow, two and one-half miles south of Fulda, Texas. No. 2: Breaks of the Little Wichita, one-half mile south of the river, and four miles southeast of Fulda, Tex. The beds are just over the bone-bearing limestone. The species in bold-faced type are characteristic of the Permian.

Locality No. 1	Locality No. 2
Pecopteris arborescens	Pecopteris hemitelioides
Pecopteris hemitelioides	Pecopteris grandifolia
Pecopteris densifolia ?	Pecopteris candolleana
Pecopteris grandifolia	Pecopteris tenuinervis
Pecopteris mertensioides ?	Diplothmema ? sp.
Gigantopteris sp. (cf. nicotianifolia)	**Odontopteris fischeri ?**
Neuropteris (cf. lindahli)	**Odontopteris neuropteroides**
Aphlebia sp.	Neuropteris cordata
Taeniopteris multinervis	**Taeniopteris coriacea ?**
Annularia spicata	**Taeniopteris abnormis**
Sphenophyllum ? sp.	**Taeniopteris n. sp.**
Sigillariostrobus hastatus	**Sphenophyllum obovatum**
Walchia schneideri ?	Sigillaria sp. (leaf)
Gomphostrobus bifidus	**Gomphostrobus ? sp.**
Cardiocarpon n. sp.	Cordaites principalis
Carpolithes sp.	**Poacordaites cf. tenuifolius**
Pelecypods	**Walchia piniformis**
Estheria and fish scales	Aspidiopsis sp.
	Araucarites n. sp.
	Cardiocarpon n. sp.
	Insect wings
	Estheria
	Anthracosia
	Ostracods and fish scales

CORRELATIONS

That the limestone series of Baylor County is the equivalent of the "Albany" formation of the southern area is fully established by both the stratigraphic and the faunal evidence. The beds in the northern area, which include the limestones, shales, and sandstones of Baylor County and the sandstones and shales of Archer and Wichita counties, constitute the Wichita formation. Our investigations therefore fully support the conclusions of Cummins[1] and Adams[2] as to the equivalency of the "Albany" and Wichita formations.[3]

[1] W. C. Cummins, *Transactions of the Texas Academy of Science*, II (1897), 93–97.

[2] George I. Adams, *Bulletin of the Geological Society of America*, XIV (1903), 191–200.

[3] Along with the limestones of northeastern Baylor County which Cummins has designated as the top of the Wichita the writer would include the overlying beds of shale and limestone mapped by him as Clear Fork, which outcrop in the banks of the Big Wichita about a mile east of the Seymour-Vernon road and northward on Beaver Creek.

Gould[1] correlated the Clear Fork with the Enid, Blaine, and Woodward formations of Oklahoma. In making this correlation, he evidently followed Cummins' earlier writings, in which the beds of Baylor County were considered to be Clear Fork. Williston states[2] that the Enid formation of Gould is identical with the beds of Baylor County.

NOMENCLATURE

In the paper cited, Adams has contended that the terms Wichita, Clear Fork, and Double Mountain should be discarded as having no stratigraphical significance. In his latest papers, Cummins recommends the abandonment of the term Albany and the use of the term Wichita for the formation. In view of the conflicting statements that have been made as to the relations of the beds called Wichita we were at first inclined to agree with the first-named writer in recommending the abandonment of the term Wichita. Further consideration, however, leads us to conclude that with a revised definition it will be best to retain the name Wichita for the formation overlying the Cisco, which it is now generally agreed should be regarded as of lower Permian age, and to abandon the name "Albany."

The series of red clays and sandstones with their included gypsum deposits which in Texas overlie the Wichita formation and to which the names Clear Fork and Double Mountain have been given have not as yet received much study. With the limited amount of knowledge available the attempt to subdivide these beds seems to the author unwarranted, and they are, therefore, here mapped as "undifferentiated Clear Fork and Double Mountain."

CLASSIFICATIONS

The Permian age of the beds to which the name of Wichita was originally applied has been accepted quite generally, though there are not wanting those who regard the evidence as unsatisfactory. It was based chiefly upon the vertebrate and plant remains. In the southward, or "Albany," area the beds are wholly marine and

[1] C. N. Gould, *Water-Supply Paper No. 154*, U.S. Geological Survey (1906), 17.

[2] Letter to the author dated August 6, 1909.

destitute of both plants and vertebrates, though abounding in the remains of invertebrates. The Pennsylvanian aspect of this fauna has strongly impressed some investigators, including the author of this paper, and doubt was entertained as to whether the plane of separation between the Pennsylvanian and the Permian should be drawn at the base or at the top of the formation. The studies of David White, Beede, and others have contributed much in recent years to a knowledge of the Permian in American and in the main support the view of the Permian age of the Wichita formation. In a recent paper Beede[1] has ably discussed the Permian of Kansas, with which he correlates the "Red Beds" of Texas. Cummins correlates the beds of eastern Baylor County which he regards as the top of the Wichita formation with the Fort Riley limestone of the Chase group of Kansas. "It is quite certain that the Fort Riley horizon is the same as the Wichita of Texas and is at the very top of the division."[2] The top boundary of the Wichita formation was drawn by Cummins[3] at the top of a stratum of red clay overlain by thin beds of limestone and blue shales at a point on the Big Wichita four miles west of the east boundary of Baylor County. However, as we have shown, beds which are undoubtedly the same as those which appear at Seymour and southward in Throckmorton County appear in the banks of the Big Wichita River some eight to ten miles west of this point. The thickness of the strata included here, which overlie Cummins' topmost beds, and are here included with them in the Wichita formation, is estimated to be 250 to 300 feet. The whole limestone and shale series of Baylor County, thus included as the upper division of the Wichita formation, is provisionally placed at 450 to 500 feet, and consists, as shown elsewhere, of limestone beds of varying thicknesses separated by varying but usually great thicknesses of shale.

How much of this is to be correlated with the Fort Riley limestones can be determined only by more detailed stratigraphic and paleontologic studies. Cummins evidently intended to include

[1] J. N. Beede, *Journal of Geology*, XVII (1909), 710–29; *Kansas University Science Bulletin*, IV, No. 3 (1907).

[2] W. F. Cummins, *Transactions of the Texas Academy of Science*, II (1897), 98.

[3] *Second Annual Report, Texas Geological Survey* (1891), 402, 403; also *Fourth Annual Report* (1893), 224.

the lower beds only in his correlation. It may be that further studies will show that the overlying beds of the Winfield limestones of Kansas are represented here.

DISCUSSION BY GEORGE H. GIRTY

The equivalence in a general way of the fossiliferous late Carboniferous beds of Kansas and Texas has long been recognized and in both cases they have very generally been cited as Permian. Cummins,[1] partly on stratigraphic and partly on paleontologic evidence, reached the conclusion that the Fort Riley limestone of Kansas occupies a position at the top of the Wichita formation of Texas. The Fort Riley is the middle formation of the Chase group, the lowest group of the Kansas Permian, so that the bottom of the Wichita may well be as low as the base of the Permian of Kansas. This correlation of Cummins is probably the most precise and the best sustained of any, and it is also in accord with some recent paleobotanic evidence. Mr. White states in the present paper in discussing the fossil plants which he obtained from the Wichita formation that the latter is probably referable to the Chase group of Kansas.

Not until recently, it seems to me, has adequate evidence been adduced either for distinguishing the Permian of Kansas and that of Texas sharply from the underlying Pennsylvanian or for correlating them with the Permian of Europe. C. A. White found the Wichita fauna to have essentially a Pennsylvanian ("Coal Measures") facies, in which, however, certain characteristic Permian Ammonites occur. A similar conclusion seems to be demanded by the evidence of the present collections.

In all, 75 species have been discriminated in the Wichita collections which I have studied, the local distribution of which is shown in the table prepared by Mr. Gordon accompanying the present paper. The identifications naturally vary in precision and refinement. In many cases it has been possible to name only the genus to which a species belongs. This is sometimes due to the fact that the species is undescribed. In a few instances species have been cited by comparison with others, e.g., *Bellerophon aff. harrodi*.

[1] *Trans. Texas Acad. Sci.*, II (1897), 98.

If such citations are included as species identified, 48 species of the fauna are identified and 27 are unidentified. Of the 48 species identified, 37 are known to occur in the Pennsylvanian rocks of the Mississippi Valley. Most of them are cited by Dr. Beede in his table showing the Pennsylvanian faunas of Kansas. The large percentage of indeterminata introduces a considerable possibility of error in the inference that 75 per cent of the fauna of the Wichita formation consists of well-known Pennsylvanian types, but it is undoubtedly true that in the main this fauna has a Pennsylvanian facies. One or two new forms at present excluded from the identified species would somewhat decrease this percentage. On the other hand, of the 25 per cent which is not known to occur in the Pennsylvanian of the Mississippi Valley, relatively few species are characteristic of the Permian of that area; still fewer, if any, are characteristic of the Permian of Europe. Some of them occur in western faunas, probably contemporaneous with the eastern Pennsylvanian. *Bellerophon subpapillosus* is one of these. Twenty-five in a hundred, therefore, far overstates the percentage of characteristic Permian species. Such percentage, however, might be considerably increased by the inclusion of certain species known to occur in the Wichita formation but not represented in the Survey collections. I refer especially to the Ammonite forms described by C. A. White from the Military Crossing of the Wichita. These are by all means the most diagnostic Permian types of the fauna. How little characteristic of it they really are, however, is shown by the fact that later collections made at the same place fail to contain them, although a special search was made to secure additional representatives.

Mr. White finds that about 50 per cent of the Wichita flora consists of species characteristic of the Permian, while most of the remainder are known to occur in rocks regarded as of Permian age. If we omit the fauna of the Kansas Permian, to include which would be a sort of *circulus vitiosus*, no condition comparable to this has been demonstrated by the invertebrate fossils and, in so far as I have seen the evidence, no such condition exists. I am, therefore, accepting the Permian age of the Kansas and Texas beds, but at present strictly on the paleobotanic evidence.

If the upper part of the Carboniferous section of Texas is to be discriminated as Permian, the line of division, as indicated also by the paleobotanic evidence, would probably best be taken at the base of the Wichita.

An inspection of the faunas collected from the strata immediately concerned in this report shows a rather noteworthy change of facies between the Wichita and the Cisco—a change, however, which is more or less progressive and has its beginning in earlier beds. This shows itself rather in a limitation than in a change of fauna and in the prominence of certain groups more rare below. Thus the brachiopods, pelecypods, gasteropods, etc., are much less in evidence in the Wichita than in the Cisco, but, as already pointed out by C. A. White,[1] they are essentially the same as those of the normal Pennsylvanian fauna. In the Wichita, however, we have a remarkable development of the Cephalopoda, which in the earlier sediments are rare.

Just what significance faunal changes of this sort possess it is difficult to say. It seems to be a change comparable to that which is more strikingly illustrated when a thin calcareous sheet with a marine fauna occurs in the middle of a coal deposit. Here, of course, there is an absolute change from the animal life of the calcareous stratum to the plant life of the coal and roof shale, but in this case the significance is not ambiguous and it is clearly not stratigraphic.[2] So I think the faunal change marked by a substitution of one predominating animal type for another may often be more safely interpreted as environmental than as stratigraphic in its import. At the same time the stratigraphic significance may be present also, which would appear to be the case with the Wichita fauna, as indicated by the fossil plants. Nevertheless, this change, as marking the evolution from one geologic period to another, would be more impressive if the molluscan and molluscoidean groups were continued into the Wichita and with a difference of facies such as is usually found when the faunas of other systems are contrasted.

[1] *U.S. Geol. Surv., Bull.* 77 (1891), 30–39.

[2] I mean of course that there is usually no time break and no appreciable change of fauna in the general region accompanying the phenomenon.

In connection with the correlation of the Wichita formation with the Permian of Europe, it may be well once again to consider the use and definition of the term Permian.

As is well known, Murchison correlated with the English "Millstone grit" a series of sandy beds which underlies the typical Russian Permian, and therefore this series, to which the name Arta beds or Artinskian was subsequently given, was distinctly excluded from the original or typical Permian. It has since been recognized that the Arta beds are not the equivalent of the "Millstone grit," and that the fossils which they contain show affinities with both the "Upper Carboniferous" below and the Permian above. The Artinskian therefore came to be called also "Permo-Carboniferous," and by many writers it is included with the other under the name Permian.

While the typical Permian is usually underlain by the sandstones of the Artinskian, over a considerable and well-defined area a heavy series of limestones and dolomites has been found to intervene. This apparently lenticular mass has been called the Kungur-stufe, and on paleontologic evidence has been by Tschernyschew united with the Artinsk and included under the term "Permo-Carboniferous," which, therefore, comprises two divisions, the Arta beds below and the Kungur beds above.

Now, the propriety of including the original Permian and "Permo-Carboniferous" in a single group is, of course, a question quite apart from the nomenclature which should be used, and it is a question with regard to which one who has not studied the rocks and fossils in the typical region can hardly render an authoritative opinion. There seems to be European authority both for excluding the "Permo-Carboniferous" from the Permian and for including it with it, the greater number of writers, it may be, adopting the latter course.

As for the plants, Mr. White states that "from the paleobotanical standpoint the Artinsk stage of Russia is clearly Permian."

My own knowledge of the facts is only that of the library, but I should judge that the faunal break was greater between the Gschelian and the "Permo-Carboniferous" than between the "Permo-Carboniferous" and the original Permian. That is, of the

very varied brachiopod fauna described by Tschernyschew from the Gschel but a small number of species appear to pass over into the Artinsk, and I infer that much the same is true of other groups. Both for this reason and because the Artinsk seems to introduce a new "cycle of deposition," I would be disposed to group the "Permo-Carboniferous" with the beds above rather than the beds below, not feeling, however, that my opinion on this point deserves much weight.

Now, while there may be diversity of opinion about grouping together the "Permo-Carboniferous" and Permian, all must agree that it is bad usage to employ the name Permian in two different senses, especially for the whole and at the same time for a part. Although the question is international as well as national, the proposition to remedy the present unfortunate condition would come with greater force and propriety from European writers. To me, personally, it is naturally a matter of indifference whether the term Permian is used for the series and a new name introduced for the beds above the "Permo-Carboniferous," or used for the beds above the "Permo-Carboniferous" and a new name introduced for the series.[1] The former alternative has in its favor the fact of perhaps greater usage; the latter, that it is the original and authoritative usage. I cannot believe that the unscientific procedure of employing the term in two senses will continue indefinitely, and consequently whatever we now do, short of the fundamental courses just named, must be more or less of a makeshift. It does not, perhaps, make much difference which method is adopted in this provisional manner, but as the main object is to be clear and exact, it has to me seemed the better plan to use Permian in the original and authentic sense.

It seems to me obvious that the Artinskian and Permian should be assembled under one division or separated into several, entirely as the sum of the evidence from all sources dictates. I have not the personal acquaintance with the beds, their faunas and floras, their field relations, etc., which would entitle me to an opinion of my own as to how they should be classified. It seems to be a moot

[1] Possibly some older name could be revived for the Permo-Carboniferous and Permian, such as Dyas, as suggested by David White.

point whether the Arta beds should be regarded as a separate division or included with the Permian, and it matters little for purposes of correlation whether an American writer follows one group of authorities rather than the other. Personally, I am quite willing to include them both in a single division of the time scale, and although believing that propriety would be better served by retaining Permian for only the upper division, I am willing to extend that term to cover the entire series because of the usage which it has received in this sense, but I am not willing, for reasons which must be obvious, to call the whole Permian and the upper part also Permian, and for the sake of precision I have been temporarily calling the upper beds Permian, the lower beds "Permo-Carboniferous," and the whole "Permo-Carboniferous" and Permian. If, in my Guadalupian report and elsewhere, I restricted the term Permian to the supra-Artinskian beds, it was done as a matter of procedure in nomenclature. I had no opinion of my own as to the classification of the beds to express or defend, although, if I had, excellent authority could be named in support of my position.

DISCUSSION BY DAVID WHITE

The plant material collected by myself from the breaks of the Little Wichita River near Fulda, Tex., is derived from two near-by localities, both near the middle of the Wichita formation. The fossil plants previously listed by Fontaine and White from two other localities, and recorded[1] by them as Permian, appear to represent a mixed flora, one of the localities being under suspicion of Pennsylvanian age. Neither of the latter two localities was visited by me on account of the lack of time; but on the basis of information received, I am disposed to believe that the stratigraphically lower beds at Antelope are probably Pennsylvanian.

The identifications given on p. 122 are provisional. Later it is hoped, when the material will have been increased both geographically and stratigraphically, a formal report covering the floras of the "Red Beds" will be prepared. The species printed bold-face in the lists on p. 122 are characteristic of the Permian. They point somewhat distinctly to the Rothliegende age of the beds.

[1] *Bull. Geol. Soc. Amer.*, III (1892), 217.

All the Old World species in the lists occur in the Permian of western Europe, and of the remaining species apparently every one which is not new is found in the Permian of Kansas. *Taeniopteris*, in simple fronds, is represented by several species characteristically lower Permian. Other types proper to the Permian are the *Odontopteris* form, the genus *Gomphostrobus*, *Annularia spicata*, the *Sphenophyllum* forms, one of which approaches *S. stoukenbergii*, and the scales provisionally referred to *Araucarites*, while the presence of *Walchia* assures a horizon as high as the highest "Coal Measures."

The presence of *Gigantopteris*, abundant at locality No. 2, is particularly notable since the genus is not definitely known except from the coal fields of central and southern China, where it occurs in beds associated with the coals overlying other terranes which, on the evidence of their contained invertebrates, have been referred by the French geologists to the lower Permian. The genus is certainly close to, if not actually identical with, a form described from several small fragments from the Permian of the Ural region.

In accordance with the paleobotanical standards of western Europe, I refer the plants of the Little Wichita in Texas to the lower Permian, the terranes being probably referable to the Chase group in Kansas. In this connection it should be observed, however, that the Artinskian flora of the Urals is essentially Permian, and that paleobotanists universally agree with the general usage of the geologists of western Europe in referring the Artinsk to the Permian.

DESCRIPTION OF LOCALITIES

NOTE.—The number at the left is the locality number as given at the head of the list and indicated on the map. The first numbers following the description of locality are the Survey permanent record numbers, the second the temporary or field numbers.

1. Bar-X Crossing, Big Wichita River, three miles north of Fulda Station, 5247 (G1. 67).

2. Bluff of Wichita River, one mile west of Bar-X ranch house, 5243 (R1. 29).

3. One mile east of Old Military Crossing, Wichita River, 7025*a*.

4. Two miles north of Wichita River, near Old Military Crossing, 7025*b*.

LOCALITY LIST OF INVERTEBRATE FOSSILS FROM THE WICHITA FORMATION, TEXAS

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Allerisma terminale									×									×	×							
terminale var.																										×
Ambocoelia planiconvexa									×	×	×			×					×		×				×	
Annelid n.g.n.sp.															×							×			×	
Aviculipecten aff. whitei																										
sp.																										
Aviculipinna nebraskensis							×		×																	
peracuta																				×	×					×
sp.																		×							×	
Astartella concentrica							×					×														
Bakewellia? sp.			×			×			×									×	×						×	×
Bellerophon crassus												×														
aff. harrodi				×									×													
sp.																										
Bucanopsis meekana													×					×								
Chonetes sp.																										
Composita subtilita								×	×		×							×	×			×				
Coloceras globulare																										
Deltopecten occidentalis																×								×		
Dentalium sp.													×			×					×	×				×
Derbya cymbula							×					×														
sp.									×																	
Entomis sp.							×																			
Estheria dawsoni											×															×
Euomphalus pernodosus																										
catilloides							×																			
sp.									×																	
Euphemus subpapillosus																										
Fusulina sp.																		×	×							
Fistulipora sp.																			×							
Fenestella sp.			×			×		×	×								×	×								
Leperditia sp.							×																			
Lingula aff. tighti								×						×												
aff. carbonaria																			×							
sp.																										
Lophophyllum profundum																										

Loxonema (sev. sp.)
Meekella striaticostata
Murchisonia aff. terebra
sp.
Myalina perattenuata
deltoidea
permiana
Nalicopsis sp.
Nautilus sp.
Nucula aff. beyrichii
Orthoceras sp.
Pelecypoda indet.
Petellostium montfortianum
Phacoceras dumblei
Phyllopora sp.
Plagioglypta aff. canna
Pleurophorus calhouni
subcuneatus
sp.
Productus cora
semireticulatus
Rhombopora lepidodendroides
Schizodus compressus
ulrichi
sp.
Sedgewickia topekensis
Septopora biserialis
Sphaerodoma intercalaris
sp.
Spirorbis sp.
Stenopora sp.
Strophostylus nanus
peoriensis
remex
Tainoceras occidentale
cavatum
Temnocheilus aff. depressum
aff. forbesianum
Zygopleura aff. rugosa

5. Four to five miles northwest of Old Military Crossing, Wichita River, 7025, 7025*c*.

6. Near Old Military Crossing, Wichita River, 7025*d*.

7. Three miles northwest of Fulda Station, near No. 2, 7026.

8. Four miles northwest of Mabelle Station (section house), 7028.

9. Eight miles southeast of Seymour, 5998 Deep Creek.

10. Head of Godwin Creek in eastern Baylor County, 7031, 7031*a*.

11. Godwin Creek near county line on Seymour-Archer city road, 5242 (R1. 29).

12. One to two miles northeast of Spring Creek, Young County (R1. 30).

13. One mile west of Spring Creek, 7035 (G1. 12, G1. 14).

14. Five miles south of Spring Creek, in Butte, 5216 (G1. 11).

15. Seven miles south of Spring Creek, Young County, 5217 (G1. 15).

16. Rocky Ford, Salt Fork, southeast corner of Baylor County, 5218 (G1. 9).

17. Quarry bank of Salt Fork, Seymour, 5220 (G1. 7).

18. West bank of Salt Fork, eight miles south of Seymour, 5222 (G1. 35).

19. Nine and one-half miles south of Seymour, Miller's Creek, 5221, 5224 (G1. 34).

20. Buttes, near wagon road, half-way between Throckmorton and Seymour, 7036 (G1. 32).

21. Three miles north of Throckmorton, 5215, 5227 (G1. 30).

22. Five miles west of Woodson, Throckmorton County, 5219, 5223, 5223*a* (G1. 25, G1. 26, G1. 27).

23. Fane Mountain, three miles southwest of Murray P.O., 5226 (G1. 24).

24. Paint Creek, southeast corner of Haskell County, 5245 (R1. 32).

25. Clear Fork, near southeast corner of Haskell County, 5231, 5232, 5241 (B1. 6, B1. 7, B1. 8).

26. Round Mountain on the Clear Fork, near 25, 5237, 5237*a* (R1. 34).

NOTES ON THE OSTEOLOGY OF THE SKULL OF PARIOTICHUS

E. B. BRANSON
The University of Missouri

In the summer of 1910 Dr. S. W. Williston asked the writer to study the Pariotichus skulls in Walker Geological Museum of the University of Chicago to see if they would throw any light on some of the undecided points concerning the osteology of that genus. The material was fragmentary with the exception of one remarkable specimen of *Pariotichus laticeps* Williston, a skull of *Pariotichus aguti* Cope?, and the base of a skull of an unidentified species. Some of the undecided questions were: Are squamosal and prosquamosal both present? Is there a distinct quadratojugal? What are the homologies of the tabulare, if such a bone is present? What are the homologies of the so-called epiotics, quadratojugals of Case? Is a presphenoid present? and What is the arrangement of the bones in the base of the skull?

The writer's thanks are due Dr. Williston for the use of the specimens and for discussions during the investigation.

In a paper published in 1878[1] Cope gave the name *Pariotichus brachyops* to an imperfect skull from the Permian of Texas, and later in the same paper described a more perfect skull as *Ectocynodon ordinatus*. As he supposed that the former had the roof of the skull unsculptured he referred the specimens to different genera. In 1882 he described *Ectocynodon aguti*[2] and in 1888 *Ectocynodon incisivus*.[3] In 1896 he referred all of the Ectocynodonts to Pariotichus and named two more species, *P. aduncus*[4] and *P. isolomus*.[5] In the paper where he named the latter he described

[1] *Proc. Am. Philos. Soc.*, XVII, 508.

[2] *Ibid.*, XX, 290.

[3] *Trans. Am. Philos. Soc.*, XVI, 290.

[4] *Proc. Am. Philos. Soc.*, XXXV, 135.

[5] *Ibid.*, XXXIV, 145.

Captorhinus angusticeps, which has recently been referred to Pariotichus by Broom.[1] In 1909 Williston described and figured *Pariotichus laticeps*.[2]

Roof of skull.—No separation of the squamosal into two bones was observed in either Pariotichus or the closely related genus Labidosaurus. Williston first called attention to this in Labidosaurus[3] and Broom shows no separation in his figures of Pariotichus.[4]

A quadratojugal is present in its normal position in the temporal region and this bone is also present in Labidosaurus. Its distinctness is not apparent in the type specimen of *Pariotichus laticeps* Williston, and was first noted in a specimen of Labidosaurus recently acquired by Walker Geological Museum, and corroborated by examination of other specimens. Dr. Case calls an element in the base of the skull the quadratojugal, but it seems to be a part of the squamosal. This part of the squamosal is indicated by the numeral "2" in Fig. 3. In a specimen of Labidosaurus figured by Williston, this part of the bone seems to be separate, but in all other specimens examined there is no evidence of separation. Dr. Williston worked over all of the skulls of Pariotichus and Labidosaurus in the Walker Geological Museum to see if we agreed on this point and we are now in accord in saying that this is probably not a separate element.

In 1883 in describing *Pariotichus megalops*, since referred to Isodectes, Cope said: "At the extreme posterior angle is a very small element in contact with the supraoccipital which may be the true intercalare."[5] In 1896 he figured this bone in *Pariotichus aguti* Cope,[6] and Case[7] and Broom[8] figure it in *Pariotichus angusticeps* Cope. It is present in the form figured in this paper; and in one or two other specimens of Pariotichus examined by the writer

[1] *Bull. Am. Mus. Nat. Hist.*, XXVIII, 218.

[2] *Biol. Bull.*, XVII, 241–55.

[3] *Am. Jour. Anat.*, X (1910), 74.

[4] *Bull. Am. Mus. Nat. Hist.*, XXVIII, 218.

[5] *Proc. Am. Philos. Soc.*, XX, 630.

[6] *Am. Naturalist*, XXX, Pl. VII.

[7] *Bull. Am. Mus. Nat. Hist.*, XXVIII, 194.

[8] *Ibid.*, XXVIII, 218.

it is distinctly separated from the parietal, but there is no indication of it in Labidosaurus. Cope also applied the name tabulare to the element and recently Broom has suggested the name post-temporal. There seems to be no valid objection to tabulare and it has the advantage of priority over Broom's name.

All writers seem to be agreed about the rest of the bones in the roof of the shull.

Base of skull.—The bases of several skulls examined during the investigation were fairly well preserved and the one from which Fig. 3 was made is almost perfect. This shows the post-parietals in the same position as figured by Williston in Labidosaurus[1] and by Case in Edaphosaurus[2] and Pariotichus. (Case calls them epiotics in Edaphosaurus.)

The exoccipitals are large and articulate with the squamosals after passing in front of the inturned edge of the latter, the quadratojugals of Case. The stapes, tympanic of Broom, articulates at its distal end with the lower inner end of the quadrate. In the drawing it is not shown distinctly separated from the exoccipital, the sutures not having been determined. The separation in this form is probably as shown by Williston in Labidosaurus.

The position of the quadrate is almost vertical with a broad bladelike process above and a heavy expanded portion below. The bladelike portion projects forward almost parallel with the median line of the skull, and the posterior end of the pterygoid rests against it. Its upper end comes in contact with the squamosal and the outer side of the base touches the quadratojugal.

Floor of skull.—The pterygoids extend from near the posterior end of the skull almost to the anterior end. They meet in the median line and are not separated by the basisphenoid as shown by Broom in *Pariotichus angusticeps* Cope.[3] The sutures between the long slender palatines and the pterygoids were made out in one specimen from the anterior end to near the posterior end, as shown by solid lines in the drawing. There are strong indications of a transverse as shown by broken lines in Fig. 4, but the evidence

[1] *Amer. Jour. Anat.*, X, Pl. III, Fig. 4.

[2] *Revision of the Pelycosauria of North America*, 1907, p. 153.

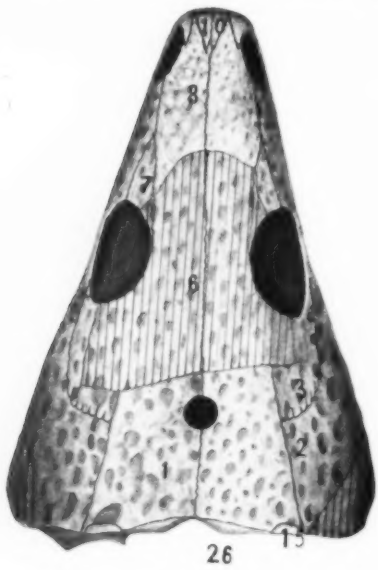
[3] *Bull. Am. Mus. Nat. Hist.*, XXVIII (1910), 218.

is not entirely convincing. The presphenoid is perfectly preserved in one specimen in Walker Geological Museum but is lost in all others examined. It is slender and extends about half the distance from the basisphenoid to the anterior end of the skull. The sutures between the vomers and palatines are not evident in any of the specimens studied.

In the specimen shown in Figs. 1 and 2, which is probably *Pariotichus aguti* Cope, though it has only two teeth on the premaxillaries, the teeth on the maxillae are in one row to behind the fifth where a second row begins inside the first, and behind this two other rather indistinctly defined rows appear. Nearly all of the teeth are subcircular in cross-section near the base, but some of the posterior ones are more or less compressed laterally.

The distinction between Pariotichus and Labidosaurus made by Cope, that the latter had the teeth of the maxillae in one row, breaks down in the Walker Geological Museum specimens. In two specimens examined during the present investigation a second row of teeth is evident and in other specimens the preservation is not such as to show whether there is more than one row.

Mandible.—The dentary makes up the outer part of the anterior half of the mandible. Just behind the dentary there is a short coronoid which occupies about one-third of the width of the jaw and sends upward a very large coronoid process almost equal in width to the rest of the mandible. Behind the coronoid the angular makes up most of the outer part of the posterior half of the jaw, and also sends forward a slender process between the dentary and the splenial, which reaches almost to the tip of the mandible. Above the angular and separated from it by a suture that runs diagonally across the jaw and passes to the posterior inferior corner, there seems to be a surangular. The splenial is not well preserved in any specimen observed and all that can be determined is that it is a broad flat bone on the inside of the jaw. The articular is imperfect in all of the specimens, but in a perfect specimen of a closely allied form, found completely separated from the other bones of the jaw, it is heavy at the posterior end and sends a long slender process forward.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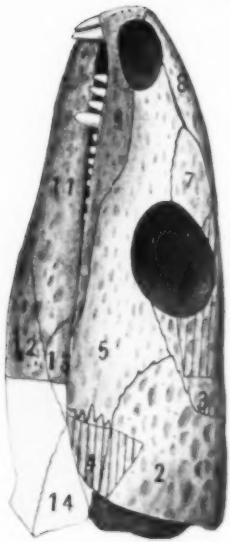
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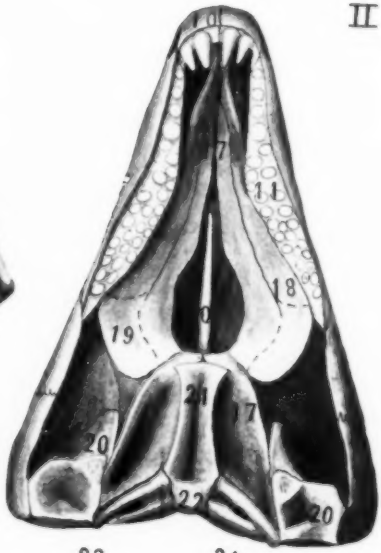
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IV

EXPLANATION OF PLATE

(The figures on this plate are natural size)

FIG. 1.—Top view of skull of *Pariotichus aguti* Cope.

FIG. 2.—Lateral view of skull of *Pariotichus aguti* Cope.

FIG. 3.—Base of skull of Pariotichus, species unidentified.

FIG. 4.—Floor of skull of Pariotichus restored from three specimens.

1, parietal; 2, squamosal; 3, postorbital; 4, quadratojugal; 5, jugal; 6, frontal; 7, prefrontal; 8, nasal; 9, maxilla; 10, premaxillae; 11, dentary; 12, angular; 13, coronoid; 14, surangular; 15, tabulare; 16, vomer; 17, pterygoids; 18, palatines; 19, transverse; 20, quadrate; 21, basisphenoid; 22, basioccipital; 23, stapes; 24, exoccipital; 25, supraoccipital; 26, postparietal. (As the surface sculpture was not well preserved in any of the specimens no attempt was made to reproduce it exactly in the drawings.) Lined areas are restored.

HIGH TERRACES AND ABANDONED VALLEYS IN WESTERN PENNSYLVANIA[1]

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The terraces with which this paper has to do are the well-known gravel-covered rock shelves found along the Allegheny, Monongahela, and other large streams of western Pennsylvania, about 200 feet above present stream channels. The abandoned parts of valleys are closely associated with the terraces, being found at the same elevation, and in many places the two are connected. Fig. 1 shows the principal areas of high terrace. The region includes all the Ohio River basin above New Martinsville, where there was formerly a divide. There are, however, terraces and abandoned parts of valleys of the same age on the Kanawha, Guyandot, Big Sandy, Kentucky, and other streams.

The impressiveness of these features is attested by the long list of names of eminent men who have studied and described parts of them. This list includes Stevenson, Leslie, Jilson, Chance, Wright, Chamberlin, Gilbert, I. C. White, Tight, Campbell, E. H. Williams, Leverett, and others.

Some of the earliest workers believed that the terraces were due to a submergence and marine erosion. Stevenson in 1879 (*Proc. Am. Phil. Soc.*, XVIII, 289–316) called attention to benches along the valley of the Monongahela and its tributaries. He divided them into a higher series of twenty benches, and a lower one of five. The higher series he attributed to marine action. They are probably entirely above those under discussion, and later work on them has shown that they are obscure and are probably due to hard layers of rock. The lower series of Stevenson seems to include those under discussion, and he refers them to stream action, without going into details of development.

[1] Published by permission of the Director of the United States Geological Survey, Washington, D.C.

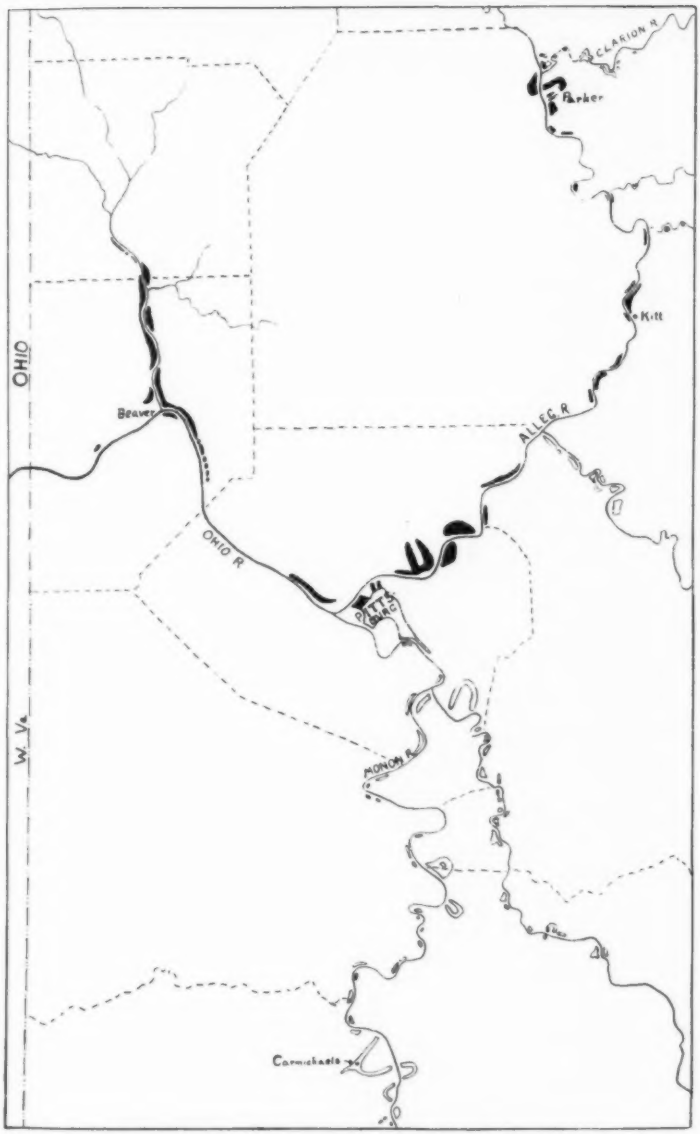

FIG. 1.—Principal areas of high terrace. Black areas have glacial gravel; those in outline have local gravel only.

In 1883 Professor G. F. Wright presented evidence of a large ice dam at Cincinnati, and shortly thereafter Professor I. C. White, in a paper before the American Association for the Advancement of Science, referred the terrace deposits of the Monongahela to that dam.

Chamberlin, in 1890 (*Bull. U.S. Geol. Surv. No. 58*, 13–38), showed that the upper series described by Stevenson could not be ascribed to the ice dam, because of their great range in altitude. He also pointed out certain characters of Stevenson's lower series which indicated that they were of fluviatile, not lacustrine, origin. These characters were: (1) the terraces slope with the present streams; (2) the material capping the terraces is distinctly fluvial; (3) they are rock platforms; (4) the form and distribution of the terraces is of fluvial, not lacustrine, order; (5) the abandoned channels must have been of stream origin.

In 1896 Professor White expressed himself (*Am. Geol.*, XVIII, December, 1896, 368–79) as still convinced that the glacial lake, Monongahela, did exist and was responsible for the terrace deposits, but that the ice dam was probably not at Cincinnati, but in the vicinity of Beaver, Pa.

In the Masontown-Uniontown folio, published in 1902, M. R. Campbell advances the theory that the deposits and abandoned channels are due to local ice dams which formed in Kansan time. He points out the fact that it is an extremely difficult and slow process for a stream to cut off any of its meander in a rugged region like Pennsylvania, and that it is impossible for a stream to establish a totally new course unless the conditions under which it operates are very different from those which normally affect the development of streams.

Again, as an objection to the view of Professor White, Mr. Campbell states that while it would be possible for a stream to change its course by superimposition if it were first caused to silt up its valley and then permitted to cut down again, he finds that part of the Carmichaels abandoned channel was not so silted up, and he therefore concludes that the change of course was not due to silting up and superimposition, but to local causes. Mr. Campbell's idea is that ice jams formed in glacial time and that these

grew until they formed huge dams 100 or more feet high, and that they persisted until deposits over 100 feet thick accumulated above them. In many cases these dams not only gave rise to terraces but caused the rivers to abandon their old valleys and cut new ones.

In the Amity folio Frederick G. Clapp expresses the belief that Professor White's theory—that of ponded waters throughout much of western Pennsylvania—will best account for the phenomena. He states that the upper limit of the stream deposits in all the valleys of southwestern Pennsylvania and parts of adjacent states has a vertical range of but little over 100 feet, but since Mr. Clapp's work was published the gravel has been found to lie at an elevation of over 1,200 feet on Clarion River, making the vertical range more than 200 feet.

The data gathered by the present writer, instead of lending support to any one of these views, seem rather to indicate that the high terraces and abandoned channels on all the rivers developed as a unit, through the overloading of the Allegheny in early glacial time.

The terraces may be divided into two groups, which have certain essential differences. Those of the first group are capped with glacial gravel, and are found along the Allegheny and Ohio. Those of the second bear material of local derivation, and are found on streams tributary to the Allegheny and Ohio. There are other differences which will be brought out later. In this connection it should be stated that there are a few remnants of older gravels, which lie at various elevations above the main high terrace formation, and in some places have been let down by erosion, so that they seem to connect with the much more extensive deposit below, but the older gravels have very slight extent.

TERRACES OF THE ALLEGHENY AND OHIO

The terraces of the Allegheny and Ohio are almost continuous from the mouth of the Clarion to Pittsburgh, and on down the Ohio. The gravel deposits on them are thin or absent where crossed by lateral streams; in other words, where erosion has been most severe; but enough remains to indicate clearly the position of the

original upper surface. At over one hundred places the upper limit of gravel has been determined by level, and that limit is in all cases very nearly 300 feet above present low water. The elevation of the rock floor beneath the deposits has also been determined at many points, and is found to be a little less than 200 feet above the present position of the rivers. Thus, the upper limit of gravel

TABLE SHOWING ELEVATIONS OF HIGH TERRACES IN WESTERN PENNSYLVANIA

Place	Miles from Beaver	Upper Limit of Gravel	Rock Floor	Present Stream	Upper Limit of Gravel above Present Stream
Foxburg quadrangle					
*One mile north of Callensburg	110	1,180	1,160±	970	230
*Turniphole	108	1,170	1,120—1,160	930	240
Mouth of Clarion River	102	1,150	1,035	846	304
Mouth of Bear Run	90	1,145	1,025	840	305
Monterey	96	1,140	1,015	832	308
Kittanning quadrangle					
Redbank	81	1,100	950	810	290
Ford City	58	1,025+	885 and 980	763	262+
New Kensington quadrangle					
Tarentum	39	1,000+	975	725	275+
Carnegie quadrangle					
Allegheny	22	1,000	896	698.4	300+
Beaver quadrangle					
Beaver	0	978	900	672	306
Latrobe quadrangle					
*One mile northeast of Blairsville	80+	1,060	....	900	160
Burgettstown quadrangle					
*One and one-half miles northeast of Burgettstown	28+	1,028	1,015	947	81

*Gravel of local derivation (not glacial).

falls regularly from 1,145 feet at Foxburg to 1,010 feet at Pittsburgh; the rock floor beneath the gravel from 1,015 to about 880 feet, and the river from 845 to 700 feet. Here, then, are three approximately parallel planes, each of which slopes about 140 feet in 80 miles. In other words, the gravel formation holds its thickness of about 125 feet, and slopes in the direction of present stream flow. See table.

The pebbles are well rounded, and lie in a matrix of sand and

clay, though in some places there is so little fine material that the gravel is dug from pits and used without further washing. In such places beds of gravel are separated by lenses of clay, but on the whole the formation is homogeneous.

That the deposit is of fluviatile and not lacustrine origin seems to be shown decisively by the characters to which Chamberlin has called attention: The deposit slopes regularly with the present streams throughout their winding courses. A lake deposit would be horizontal unless affected by crustal deformation, and in that case the slope would not change direction at just the places where the course of the river changes. Second, the material is distinctly fluvial, consisting of irregularly bedded gravel which contains lenticular masses of silt and clay. A lake deposit in a valley might have deltas containing some coarse material, but in no way could coarse glacial débris, poured into the end of a narrow lake 100 or more miles long, be evenly distributed so that the resulting formation throughout its length would be homogeneous and of uniform thickness.

There seems to be good evidence also, as Leverett has pointed out, that in pre-Glacial time the Clarion was the headwater portion of the Allegheny, a divide crossing the present course of the latter stream just above the mouth of the former, and that the glacier, by cutting off the outlets of the drainage of the area to the north, forced the water to cut across the divide to the old Lower Allegheny, thus thrusting greatness upon the Allegheny basin.

Through the new cut were discharged great volumes of glacial outwash—too great for the Allegheny to transport—and the coarsest part of the débris was spread along the bottom of the valley, forming a typical valley train which had a nearly uniform thickness throughout its length. The bodies of gravel on the high terraces of the Allegheny and Ohio, then, are the remnants of this old valley train.

The overloaded condition of the Allegheny was probably due to several causes, among which the following may be mentioned as being more or less effective: First, an actual increase in load derived from (*a*) material fed more or less directly to the streams by the glacier; (*b*) débris from the cutting of new gorges across

old divides; (*c*) material brought after the ice melted, by tributaries as they cut new valleys. Second, a decrease in velocity and carrying power, produced by (*a*) the attraction of the ice mass; within a degree of the ice front this may so have changed water level that in a stream flowing away from the ice a gradient of $1\frac{3}{4}$ feet per mile might have been reduced to $1\frac{1}{2}$ or $1\frac{1}{4}$ feet per mile; (*b*) crustal deformation, due to the weight of the ice; (*c*) the divides crossed; each of these would check the velocity and cause deposits for a short distance upstream; and ice jams operate in a similar way. Third, a possible but not probable decrease in volume, arising from a change in climate. It is probable that during Kansan time the river had a larger volume than now because it was carrying the run-off from a much larger territory.

TERRACES OF TRIBUTARY RIVERS

The second group of high-terrace deposits is found on streams tributary to the Allegheny and Ohio. Those along the Clarion River may be taken as typical and described in detail.[1] At Foxburg the high gravels of the Clarion connect and mingle with those of the Allegheny, both the rock floors and the upper surfaces of the deposits connecting, without interruption (see Fig. 3). The Clarion gravels are much like those of the Allegheny, but differ from them in the following respects: First, the material is of local, not glacial, origin. Second, the thickness decreases upstream. Third, the gravels are as a whole much finer, only the base being as coarse as the glacial gravels. There are some minor points of dissimilarity, but these are the important ones in the present discussion.

In present distribution the gravels are as continuous as those of the Allegheny. There is scarcely a half-mile of the lower part of the valley where they are absent or even approximately so.

That the Clarion terraces are of stream origin is shown by characters similar to and as decisive as those of the Allegheny terraces mentioned above, and certain important features indicate the immediate cause of the accumulation of gravel. First, at the confluence of the two rivers the high-terrace gravels correspond exactly in elevation and thickness. Second, the Clarion gravel rises and

[1] See Foxburg-Clarion folio, *U.S. Geol. Surv.* (in press).

becomes thinner and narrower upstream, and at a distance of 20 miles from the Allegheny the formation has the width, thinness, and coarseness of an ordinary flood-plain deposit.

These facts suggest at once that the Clarion terraces owe their existence to conditions on the river into which that stream discharged. When the Allegheny began to aggrade, the effect was that of a gradually growing dam across the mouth of the Clarion. This caused the latter stream to drop the coarsest part of its load. The dam did not grow so rapidly as to produce a pond in the river above, but aggradation kept pace with the growth of the dam. In other words, at its mouth the Clarion built up as rapidly as the Allegheny. This is shown by the even downstream dip of the Clarion gravels and by their coarseness. If any ponded stage had existed, the deposit would have been coarse only at the upper end of the pond and would have taken the form of a delta.

But of course the dam did not affect the Clarion throughout its length. On the contrary, when the dam began to grow, its influence was felt only in that part of the stream immediately above. As it grew the area affected by it extended farther and farther from the Allegheny and the river built up to a new gradient, over which it was just able to carry its normal load. The coarser part of the gravel was dropped where the gradient changed from the old to the new. This point gradually moved upstream and the extended coarse deposit became the basal coarse part of the formation. The Clarion then silted up because its master stream, the Allegheny, was aggrading, and the elevation of its outlet was being raised. The Allegheny aggraded because of great increase in load, the Clarion because of decrease of gradient. The absolute load of the latter stream has not changed materially since the dawn of the Quaternary period.

Space will not permit of complete description of all the high terraces, but the work of the Clarion may be taken as a type of the work of those streams which discharged into the overladen Allegheny and Ohio. Redbank Creek, the Conemaugh, Kiskiminitas, Youghiogheny, and Monongahela show similar characters. On all except the smallest of the tributaries of the Allegheny, there are deposits connecting with the early glacial valley train, such

deposits rising, thinning, and narrowing upstream, and consisting of mixed coarse and fine material of local origin, the proportion of fine being somewhat greater than in the valley train. The larger the tributary the more gradually does the deposit rise and thin, for the larger streams have less fall, and there is less difference between the old gradient, with which the streams were more than able to carry their loads, and the adjusted gradients, with which the streams did neither cut nor fill.

To illustrate, certain facts indicate that in pre-Glacial time the lower 50 miles of the Monongahela had a fall of about one foot

FIG. 2.—Longitudinal section of deposit on a stream tributary to one which is overloaded with glacial débris. A distinguishing character of such deposits is that they are definitely limited upstream by the convergence of the old profile in use when the stream was cutting down, and the adjusted profile with which the stream is just able to carry the load delivered to it by headwaters and side streams.

per mile, that the adjusted gradient was about 9 inches per mile, and that the valley train athwart the mouth of the river was about 110 feet thick. At this point the Monongahela fill should have been 110 feet thick, and this thickness should have decreased upstream by 1 foot minus 9 inches, or 3 inches per mile, and at 50 miles the formation should have been thinner by 130 inches, or $12\frac{1}{2}$ feet. The results obtained by actual observation in the field accord very closely with these figures. The deposit is nearly 100 feet thick at the West Virginia line.

As another example, the Clarion gravels thin almost 50 per cent in 10 miles. Originally, as indicated by the base of the gravels, the stream had a fall of about 125 feet in the lower 10 miles of its course. The adjusting of the gradient reduced this to 60 feet. The difference between these figures, or 65 feet, plus the thickness of the deposit at the upper end of the 10 miles, or 50 feet, is 115 feet, which is the thickness of the deposit at the lower end of the valley.

To sum up, the inferred history of the terraces reads about as follows. The Allegheny was overloaded at a certain point. The material was spread out evenly from the place of overloading. On each tributary stream deposits accumulated, first at the point of junction with the overloaded one, then farther and farther upstream. These processes continued until the load and gradient of the Allegheny were so adjusted that the river was able to carry its load. Later, probably on account of an elevation of the land, the stream has cut through its deposit and 200 feet below the level of the old rock floor.

"ABANDONED CHANNELS"

In close association with the high terraces are the many so-called abandoned channels or side tracks to the main lines of drainage. Examples are found not only in western Pennsylvania, but along the Ohio, Mississippi, and a large number of tributary streams. Genetically these features seem to be similar, though some developed early in the Quaternary period and others later.

The abandoned part of the Monongahela valley at Carmichaels, Pa., referred to on p. 142, has been described as containing evidence of a huge local dam of ice, but to the present writer the evidence did not seem to indicate a local barrier for the following reasons: (1) The deposit thins at the position of the supposed dam not abruptly, but irregularly, and a mile or more below considerable thicknesses are found. (2) Just below the place of thinning, the formation extends up the valley side to the altitude of the upper limit of gravel, and a little farther away are extensive bodies of the deposits, fully 100 feet thick. (3) The thinner parts are found at a place where erosion has been very severe—where the gravel has been dissected by a good-sized tributary. It appears, therefore, that the thin part of the deposit is simply a result of irregular clearing-out of the old valley by the tributary and is a feature to be expected. The stream seems to have cut down quickly through the silt and gravel, but when it came to hard rock it hesitated, meandered a little, and then cut down farther, leaving the shelf covered with pebbles and bowlders concentrated from the original deposit. The fact that just below the site of the dam the formation is found

today extending up on the side of the valley and a few miles away the full thickness of over 100 feet is present, is evidence that the deposit was formerly 100 feet deep here as it is elsewhere. There could scarcely be any other possibility except that the valley-side deposit represents an older fill, and there is no foundation for such an assumption.

A theoretical consideration of the question of local ice dams yields interesting results. The possibility of an initial ice jam is not to be questioned. Moreover, the supposition that such a jam might be large in a northward or iceward flowing stream in a subglacial climate is reasonable and is supported by known conditions on the McKenzie and other streams which work under somewhat similar circumstances.

But the ice dams in this case must have been several times as high as the highest known and must have persisted through many summers warm enough to melt back the thousands of feet of ice in a continental ice sheet. Indeed if we assume that the Monongahela carried the same amount of suspended matter which it carries today (in all probability it did not carry so much), that all its load of undissolved matter was dropped, and that immediately after the reservoir became filled the dam went out, we get a minimum estimate for the life of the dam of about 1,000 years. If only a quarter of the material were dropped the time would be 4,000 years.

During this time the run-off of the basin must have passed over the dam, for if the dam had suddenly risen above the height of cols in near-by divides, the lake immediately behind the dam would not have been silted up. Moreover, considerable coarse material is found just above the supposed dam, indicating that there were strong currents and that only a small fraction of the suspended matter was dropped.

The hypothesis of an ice dam, therefore, involves the assumption that the Monongahela, which since early glacial time has, with a very low gradient, removed rock material to a depth of 200 feet for more than 100 miles, was for centuries unable to cut through or undermine these blocks of ice over which its gradient and eroding power must have been that of a cascade or waterfall. The assumed floor of the valley below the site of the dam is 60 feet below

the top of the fill above the dam. The drop in water level must have been as great or greater, and yet the dam must have withstood the pressure and the wear year after year for thousands of years.

Parker oxbow.—One of the most famous of the abandoned valleys is the old oxbow at Parker's Landing (see Fig. 3). It was first described in detail by Chance (*Second Geol. Surv. of Pa.*, Rept. VV, 1880, 17–22). He calls attention to the disproportionate size and breadth of the valleys of the two small streams which now flow from the oxbow, and also to the fact that between the heads of the streams there is low swampy ground. Glacial gravels of probable Kansan age are found almost continuously around the loop and in some places the deposit is over 50 feet thick. Chance inferred that at the time of the earliest ice advance this oxbow was occupied by the Allegheny River, and at a subsequent time the neck was severed.

G. F. Wright held that this channel was formed and abandoned before glaciation, and that the glacial material now found in the oxbow was deposited there at a time when the Allegheny, being overloaded with Kansan outwash, aggraded up to a position somewhat above the oxbow; that the gravel was carried into the ends of the loop, but the river never reoccupied the entire loop. Wright has long advocated the idea that the Allegheny was cut to about 50 feet below its present channel in pre-Glacial time, and that the glacial valley train was thus about 350 feet thick, filling the inner gorge and part of the broad valley above.

Chamberlin and Gilbert studied the problem in 1889, and their conclusions agree essentially with those of Chance, and are found in *Bulletin U.S. Geological Survey No. 58*, 31.

In 1894 Wright again published a paper (*Am. Jour. Sci.*, 3d ser., XLVII, 173–75) in which he holds to his previous conclusions.

In 1900 E. H. Williams presented a paper at the Albany meeting of the Geological Society of America (*Bull. G.S.A.*, XII, 1900, 463) in which he agreed with Wright that the river has not occupied the oxbow since the beginning of the Glacial period, but he went so far as to hold that the river never did flow around the so-called oxbow. He ascribes the feature to the work of two small streams which "rise on opposite sides of a low col and de-

FIG. 3.—Topography of "Parker oxbow" and vicinity. (Shaded part shows area occupied by high-terrace gravel.) (From Foxburg, Pa., topog. sheet, *U.S. Geol. Survey.*)

bouche into the Allegheny gorge within a mile of one another, and in Glacial time these two valleys were filled by overwash deposits mingled with material from the immediately adjacent slopes." He states also that the rock floor of the abandoned channel is not level, but falls down rapidly toward the river. He does not, however, explain the fact that the col between the heads of the two streams is low and swampy, whereas there is not a case of two large streams rising in an area of swampy ground in the whole unglaciated area of western Pennsylvania, and he says nothing about the broad steep-walled valley through which the small streams flow.

Frank Leverett (*U.S. Geol. Surv. Mon. 41*, 242) considers E. H. Williams' view "more consistent with the features than the one presented by Chance," and says further (apparently misinterpreting Williams' view): "It refers the opening of the double channel, resembling the forks of an oxbow, to a shifting of a smaller tributary of the Allegheny from one side to the other of a low hill that stood nearly opposite the point at which the tributary entered the valley."

The data gathered by the writer indicate, first, that the so-called Parker oxbow is an abandoned channel of Allegheny River, and so is properly called an oxbow. The characters which force such a conclusion are: (*a*) the depression has the size and shape of the Allegheny valley, having a comparatively uniform width of about a mile, and bounding walls from 100 to 300 feet high; (*b*) the shape is a broad smooth curve with the side of the valley inside the loop gently sloping, and that outside high and steep like the present valley around curves of the river (it resembles, for example, the curve of the Clarion 1 mile south of Turniphole, Foxburg quadrangle); (*c*) a current with something like the strength of a river must have flowed around the bend, for pebbles up to 6 inches in diameter are found at the most extreme part of the loop.

Second: The abandoned channel was occupied in a part of Kansan time. The presence of Kansan outwash on the floor, which is at nearly the same elevation as the floor under Kansan material near by, indicates that the last great event before the abandonment of the oxbow was the advance of the Kansan ice

sheet. The abandonment took place before the stream began again to cut down, for deposits are found around the loop almost as high as the highest gravel. The broad valley around the oxbow was cut previous to this time. One can only conjecture how long a period of time was necessary for this.

There is some evidence that the rock floor of the east end of the loop is higher than the Parker strath. If this be true the oxbow must have been developed either in pre-Kansan time, before the stream had cut as low as the Parker strath, or after the Allegheny had aggraded until it was high enough to take this route. However this may be, the close association of the abandoned channel with the high terrace, and the occurrence of Kansan material in the channel, show that whenever it was formed, it was occupied and abandoned in Kansan time.

Third: The length, depth, and narrowness of the rock channel through which the river now flows across the neck of the oxbow suggests that the oxbow was not cut off in the way that streams ordinarily cut off their meander, but points rather to superimposition. The present valley across the neck of the abandoned channel is a narrow rock gorge over a mile long, and the top of the gorge extends up to the level of the highest part of the old channel.

Another abandoned valley which is thought to show the method of development very well is found on the Allegheny, a few miles northeast of Pittsburgh, and opposite Verona. The topography suggests at once that this feature is a cut-off loop of the Allegheny, and it is found on a level with the high terraces. The width is nearly as great as that of the old valley of the Allegheny, and glacial gravels are found in it. But on closer inspection it is found that the width of the valley and the thickness of the deposit decrease rapidly away from the present course of the river, and this through a rise in the rock floor. Also there is an impressive amount of fine material and a scarcity of bowlders. Finally, at the extreme end of the loop the old valley, if such it be, is very narrow, and the deposit but a few feet thick.

The meaning of these features seems quite evident. At the time the Allegheny began to aggrade, the position of this loop was occupied by two small tributary streams. The divide between them

was, at one place, a little less than 100 feet above the river-valley floor. As the river rose it dropped some coarse materials in the ends of the tributary valleys, but a mile away the ponded water was quiet and the deposit fine. This process continued until the Allegheny reached the elevation of the lowest point in the divide between the streams, about 3 miles away. Then the river current was separated and a part flowed slowly up one tributary and down the other, carrying some coarse and much fine material (varying from season to season) and shaping the col into the form of a valley. Finally the river cut down again, abandoning the course which it had occupied temporarily for the much shorter original course.

A part of the history of the loop is reflected also in its present drainage. When the river left it, the run-off was naturally in the direction in which the river had flowed, out one arm and back down the other. But a new small tributary in the position of the upper one of the old ones is now cutting back into the upper end of the abandoned valley, driving the head of the other stream back and annexing a part of its unnatural drainage basin.

All of the other abandoned parts of the valleys of this region have been examined carefully and seem to have been developed in the same way—by silting up and redissection—and the process is the same whether the case be on the Allegheny or on one of the tributary streams. In many cases the new courses made available by the silting-up of the old channels were about as direct as the old, and in certain of such cases the stream cut down in its old course, while in others it assumed a new course. Thus some of the abandoned valleys mark courses temporarily occupied by the rivers, while others show old and long-used courses. It is a significant fact that the changes were, in nearly every case, from a longer route to a shorter one. This would scarcely have been true had the rivers been driven from their courses by ice dams. There are some cols which stand just a few feet higher than the highest gravel, and these were, of course, never crossed by the rivers. Indeed, if aggradation had proceeded 50 or 100 per cent farther there would have been an amazing network of long and devious "abandoned" valleys.

SUMMARY

Summarizing, the method of development of the high terraces and abandoned parts of valleys of western Pennsylvania seems to be as follows: (1) The development of a valley train over 100 feet thick, along the Allegheny and Ohio; (2) from the beginning the aggradation of this stream produced an effect felt on every tributary, and a portion of each, beginning at its mouth and extending gradually upstream, became silted up. (The lower end of each tributary valley thus took on a form resembling the half-filled character of the valley of the master stream.) (3) As the rivers built up they found themselves flowing at the height of one after another of the lowest places in near-by divides, and at such times and places the currents were divided and the cols were occupied. This overloaded condition of the streams lasted a long time and there were many fluctuations, for at some places, as at Pittsburgh and Belle Vernon, there are two or three well-developed valleys side by side. (4) When final redissection began, the rivers chose the channels momentarily most desirable. In most cases the short route was the principal factor in the choice, but in others the largest current at the time and other comparatively trivial conditions determined the courses of the streams. As in all cases of superimposition, the resistance of underlying rock played no part in their location, and at many places the rivers soon found themselves sawing into hard rock where near by were courses through unconsolidated materials.

REQUISITE CONDITIONS FOR THE FORMATION OF ICE RAMPARTS

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In a recent paper[1] Mr. J. B. Tyrrell, late of the Geological Survey of Canada, has made the assertion that though he has now for many winters made observations on and about the Canadian Lakes, he has never detected any evidence of ice push against shores as a result of expansion. He thus discredits the accepted explanation of ice ramparts. To one who has in other localities seen the ramparts *in process of formation* from this cause, it seems important to supply an explanation for the failure of such an experienced and careful observer as Mr. Tyrrell to observe the same phenomenon.

The quite obvious fact is that ice ramparts are greatly restricted in their occurrence, a number of special conditions being essential to their formation. Mr. Tyrrell's paper fortunately shows that some of these conditions were lacking in the districts which he studied.

In order that these requisite conditions may clearly be understood, it will be necessary to give in brief outline the theory of formation of normal ice ramparts through ice expansion. The initial ice cover of the winter season on our northern lakes usually forms with only moderately cold air temperatures. These may be assumed to be but a few degrees below the freezing point, and the cover, once formed to a thickness of an inch, grows quite slowly from the under surface. After it has acquired a considerable thickness, the arrival of one of the "cold waves" contracts the ice cover by lowering its temperature through contact with the colder air layers. Under this contraction fissures open in the ice to the accompaniment of loud rumblings, water rises to fill them and is

[1] J. B. Tyrrell, "Ice on Canadian Lakes," *Trans. Can. Inst.* (1910), IX, 1–9 (reprint), pls. 1–6.

quickly frozen in the prevailing low temperature so as to form intercalated "planks" of younger ice. The lake cover is thus again completed at a low temperature, so that a "warm wave," *if it can quickly communicate its temperature to the ice*, causes an expansion which according to Tyrrell amounts to one to three inches per mile per degree Fahrenheit. Thus expanded the ice cover is too large, and a push is exerted against the shore *if the cover is a structure competent to transmit the stresses induced in it.* The range of action of this push, and the consequent *size of the ridge raised upon the shore will depend upon the number of times the process is repeated;* for each alternation of "cold" and "warm" wave introduces a new series of wedges into the ice cover and correspondingly extends its margins.

To recapitulate: (1) there must be a wide and probably also a relatively sudden alternation of lower and higher air temperatures over the lake: (2) these temperature changes must be promptly communicated to the ice; (3) the ice cover regarded as a girder must be competent to transmit the stresses to the shore; and (4) for large effects the alternations of temperature must be several times repeated. Obviously, also, the shores of the lake must be of such form and materials as to be subject to movement under stresses below the crushing strength of the ice itself.

The first and last conditions are meteorological and can be determined for any given district. Not only is a severe winter climate essential, but there must be an alternating occurrence of cold and warm waves.

The second and third conditions are crucial. In Buckley's studies of ice ramparts at Madison, Wisconsin, the most thorough that have been made,[1] it was found that ramparts seldom formed during seasons when the lakes were snow covered. The probable explanation of this is that snow blankets the ice and prevents a *quick* communication to it of the air temperatures above the snow surface. We have here emphasized the element of time, for the reason that studies in Greenland show that air temperatures are *slowly* communicated downward through snow blankets to very

[1] E. R. Buckley, "Ice Ramparts," *Trans. Wis. Acad.* (1901), XIII, 141–62; pls. 1–18 (discussion by C. R. Van Hise).

considerable depths. It is well known from studies of the "fatigue" of materials under stress that they often yield to slowly acting stresses that would be transmitted undiminished in intensity if quickly applied. Snow blanketing of the ice, from the evidence in Mr. Tyrrell's paper, would appear to be very general within the districts which he studied.

Further limitations upon the formation of ice ramparts are imposed by the third condition—the incompetency of the ice cover as a transmitter of stresses. With the ice serving as a strut,

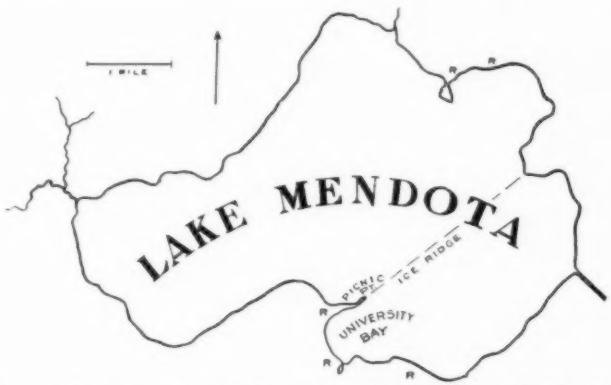


FIG. 1.—Sketch map showing the position of ice ramparts and of buckled ice ridge formed on Lake Mendota at Madison, Wisconsin (based on Buckley's Map).

its push can be transmitted effectively *only when the cover is maintained as a plane surface*. Lack of homogeneity or of absolute uniformity in strength, and variation in form of the surface at which stress is applied, will with increasing length of beam introduce an important stress component tending to buckle the beam and dissipate the energy transmitted by it—the competency of a strut to transmit stresses is inversely as its length. Experience shows that lakes or arms of lakes which are much over a mile and a half across do not develop important ice ramparts. On Lake Mendota at Madison, the best ramparts are found upon the shores of University Bay, which is about three-fourths of a mile across. Outside this bay the lake ice is raised each winter into a sharp

ridge extending from the outer margin of the bay (the peninsula of Picnic Point) across the wide portion of the lake to the opposite shore, and about this section no ramparts are developed (see Fig. 1).

Ice ramparts can thus form only on shores of lakes which have relatively small size or on small bays of larger lakes, though a width of at least half a mile is probably necessary in order to secure sufficient dilatation of the ice cover to make ramparts of appreciable size.

Anything which tends to deform the ice cover from a perfect plane will effectively destroy its competency as a girder, and then no ramparts will form. Mr. Tyrrell has shown in his valuable paper that young lake ice will support, without bending, less than its own thickness of dry snow, and that the ice on Canadian lakes is bowed down under its load of snow to such an extent that water comes to the surface through cracks and further increases the bending.

To sum up, the heavy snow cover alone would by blanketing the ice, but probably even more by bending it, effectually prevent the formation of normal ice ramparts. As already stated, such ramparts may actually be seen in process of formation during a warm wave in any favorable winter about Lake Mendota at Madison, Wisconsin.

It is fully realized that rafts of floating ice drifted by the winds at the time of the spring "break up" do also produce small bowlder ridges on shores which bear a close resemblance to some of the types of normal ice ramparts.

THE TERMINAL MORAINE OF THE PUGET SOUND GLACIER

J. HARLEN BRETZ

I. GENERAL CHARACTER OF THE COUNTRY SOUTH OF PUGET SOUND

The region of Puget Sound, inclosed between the Olympic and Cascade ranges, is a heavily drift-covered lowland. The drift is deeply incised by broad valleys of meridional trend, some occupied by arms of the Sound, some by lakes, and others by streams. The summits of the plateaus and hills of drift accord in a general level so that, seen from overlooking mountain peaks, the region appears to be a vast plain, interrupted only by a few rock hills, remnants of the preglacial topography rising above the drift.

Immediately south of the Sound the drift assumes a different facies. The trough valleys disappear and the plain becomes continuous and is widely covered with gravel outwash. It is still a part of the great Puget Sound drift plain. It is diversified with morainic eminences occasionally, of a character different from that of the drift hills lying between the valleys of Puget Sound farther north. The most southerly extended of these hills is a belt which constitutes a part of the terminal moraine of the Puget Sound glacier.

Beyond the southern portion of the Puget Sound depression is an abrupt transition in the topography. Rock hills of preglacial sculpture, lying beyond the limit of glaciation, begin here and continue southward past the Columbia. In western Washington no other such area of low rock surface occurs as must here exist beneath the heavy drift mantle of Puget Sound.

On the southeast, the area is overlooked by the magnificent Tertiary volcano Rainier. On the south is a region of rock hills bearing no group name. They are drained by the upper Des Chutes and the Skookum Chuck rivers and have a maximum altitude of about 2,000 feet. Farther west lie the Black Hills, whose highest altitude is probably not greater than 2,000 feet.

These hills are bounded on the east and northwest sides by low, wide valleys which constituted the two chief routes of glacial water discharge from the basin of Puget Sound. The Olympic foothills rise farther northwest in the main Olympic Range. At the time of greatest extent of the ice, the northern slope of the Black Hills was overridden and a lobe extended down on either side, the hills determining a broad re-entrant in the ice front.

II. PREVIOUS WORK ON THE MORAINE

In a general way, the glacial drift in Puget Sound has long been known to terminate some distance south of Olympia, and the gravel plains have been commonly recognized as outwash deposits from the ice. No detailed work, however, has been done in the region except by Willis and Smith on the Tacoma quadrangle.[1] Here the contact between Pleistocene deposits from the glaciers of the Cascades and Mt. Rainier and the Puget Sound drift has been traced along the northwest flank of the volcano to the southern edge of the quadrangle.

Warren Upham has described,[2] from a hasty reconnaissance, what he believed to be the terminal moraine lying between the base of Mt. Rainier and the Black Hills. He interpreted the remarkable gravel mounds of the outwash plains of the region as morainic topography of peculiar type.

No observer, so far as the writer is aware, has previously noted the existence of the western lobe of the glacier, lying between the Olympic Mountains and the Black Hills.

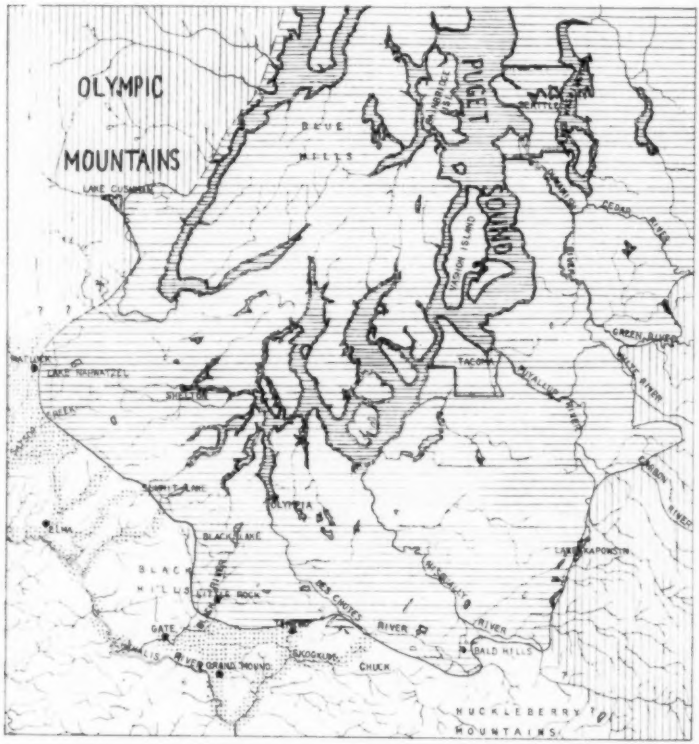
III. MORAINE COURSE ACROSS THE GEOSYNCLINE

The westernmost geosyncline of North America is regarded by stratigraphers as finding its representative on the Washington coast in the Puget Sound depression. Were it not for the accident of glaciation, this structural valley would today embrace a broad inland sea, but the thick drift deposit constitutes a filling sufficient to maintain most of the surface above sea-level. The terminal

[1] Bailey Willis and G. O. Smith, "Tacoma Folio, No. 54," *U.S. Geol. Survey.*

[2] Warren Upham, "Glacial and Modified Drift in Seattle, Tacoma and Olympia." *American Geologist*, XXIV, No. 4.

moraine is built far enough to the south to lie in general over rock surfaces above sea-level; indeed, the moraine forms a fairly con-



GLACIATION OF PUGET SOUND

Horizontal Ruling - - - - Extent of Vashon Glaciation
Vertical Ruling - - - - On East — Cascade Neve and Ice
On West — Olympic Neve and Ice
Dotted Areas - - - - - - Extra-morainic Vashon Outwash

0 10 20 30

stant boundary between the depressed region to the north, now drift filled, and the rugged, stream-carved rock hills southward.

The field work on which this paper is based has been done under some difficulty because of the undeveloped nature of the country,

and its incompleteness must largely be charged to the same reason. Large tracts about Puget Sound are yet covered with virgin forest whose density is such that passage for any considerable distance is next to impossible. The lack of roads, trails, and inhabitants over many square miles forces the investigator to shoulder his pack of blankets and food, and travel the country on foot. Detailed work is not practicable under these circumstances. It will probably be years before the moraine can be mapped with accuracy, since the task must wait on the agricultural development of the country.

On the eastern margin of the Tacoma quadrangle, Willis and Smith[1] found a broad sheet of till spread by a piedmont glacier from the Cascades. The contact between this drift sheet, named the Osceola till, and the Vashon or youngest till sheet of the Puget Sound glacier was found to be marked by a belt of hummocky topography of morainic aspect, considerably different from that of the ground moraine on either side. No definite marginal or interlobate moraines were found, the phenomena being apparently referable to subglacial accumulation. Short eskers were a notable feature.

This study has taken up the continuation of the contact between local glacial deposits, and those far traveled down the Puget Sound depression from the north, on the south edge of the Tacoma quadrangle in a densely wooded country traversed by a few secondary roads and one highway, the Mt. Rainier automobile road. The geological map of the Tacoma folio maps the Rainier Pleistocene drift on the south edge of the quadrangle, farther west than the writer has found it. The automobile road follows a north to south course for 5 or 6 miles, parallel to and about 6 miles west of Lake Kapowsin, and for this whole distance traverses the till plain of the Puget Sound Vashon glacier. Northward toward Tacoma are extensive areas of outwash gravel deposited during the recession of the Puget Sound ice. The till plain rises southward from the outwash with an abrupt morainic slope, ascending 200 feet in one mile. The slope is thrown into several successive ridges of till trending east to west, on the south sides of some of which were

[1] Bailey Willis and G. O. Smith, *op. cit.*

distinct kames. The till is the characteristic blue-gray arenaceous material, with laminae and rounded cobbles, which is identified throughout the Puget Sound country as Vashon. The presence of numerous varieties of rolled granite cobbles in the moraine and in the plain southward is a safe criterion for the identification of the till as the Vashon rather than the Osceola till of the Cascades. The moraine ridges on its northern flank and broad till plain lying southward are topographic features in accord with this interpretation. Though the boundary between Vashon and Osceola till was not located, it obviously lies between the Mt. Rainier highway and Lake Kapowsin, the lake lying at the base of the foothills of Mt. Rainier.

The dominance of Puget Sound ice at the western base of the Rainier foothill country is proved conclusively by the common occurrence of bowlders and cobbles of several granitic types characteristic of the drift of Puget Sound and unknown to the adjacent Cascades.

The postglacial gorge of Nisqually River, 300 feet in maximum depth and with vertical and even overhanging walls, is two miles long and occurs where the river enters the area of Puget Sound drift. A 40-foot section of outwash, containing frequent Vashon drift materials, overlies the rock floor in which the canyon is cut at LeGrande. Farther up the canyon no drift was found.

A trail crosses the divide between the Nisqually and Des Chutes rivers just south of the canyon noted, entering the latter stream at the headwaters. Scattered granitic bowlders of Vashon drift were found up to an altitude of 1,220 feet on the Nisqually side, but no traces of drift were found in the remaining 200 feet of ascent or in the valley of the Des Chutes on the other side until the altitude of 1,200 feet was reached, a few miles down from the headwaters. Here scattered erratics occur on the hillsides, and at 900 feet is a level terrace composed of fine material with interspersed pebbles, probably a lacustrine deposit caused by the ice entering the lower valley and blocking the drainage.

Two miles below this terrace, whose soil has determined the location of several small farms in the wilderness, is found the terminal moraine of the Puget Sound Vashon glacier. The surface is exceed-

ingly bowldery, granite is very abundant, kettles containing lakelets and bogs are common, and the subsoil is typical Vashon till. The margin of this bowldery drift may be traced about the west and north of the Bald Hills from the Des Chutes to the Nisqually River and is in places thrown into sharply defined ridges. Occasionally the forest seems growing on one gigantic bowlder heap. A preglacial valley descending to the northwest has been dammed, giving rise to Little Bald Hill Lake, a picturesque body of water in the heart of the wilderness. Another such valley has three morainic ridges thrown across it at descending altitudes, a marsh or alluvial flat lying behind each ridge. Pronounced relief of the moraine on the north slope of the Bald Hills was found, but the unbroken forest prevented satisfactory examination.

The same difficulty of examination is presented by most of the country from the Bald Hills west to Tenino. In general, the drift-covered area bears the farms and roads, the region immediately beyond the ice limit rising in rocky hills which constitute the divide between the Des Chutes River and the Skookum Chuck. A traverse across this divide found the moraine disposed in bowldery ridges along the base of the hills with a marginal drainage channel separating the frontal ridge from the bold rock hill slope. No erratic material or evidence of ice action was found on the ascent to the divide crest, the glacier of Puget Sound having succeeded in barely reaching the northern base of the hill region.

The town of Tenino is situated on an area of gravel outwash lying immediately south of the moraine. The rock hills die away toward the west just south of the town and glacial drainage escaped southward to the lower Skookum Chuck through a broad, gravel-filled valley. Glacial outwash was also carried westward from Tenino toward Grand Mound and Gate to join the extensive areas there outspread.

The Skookum Chuck bears a train of glacial gravel which entered it somewhere in the unsurveyed region of the Huckleberry Mountains, presumably from Mt. Rainier's Pleistocene glaciers. But careful search revealed absolutely no granite or sedimentary metamorphics in this gravel for a distance of 6 miles along its course. Only when the western limits of the rock hills were approached,

and below a low pass across the divide to the Des Chutes River, was Puget Sound glacial gravel found in the Skookum Chuck valley.

Clear Lake, at McIntosh station, 4 miles east of Tenino, lies in a marginal drainage channel discharging westward into the outwash gravel area at Tenino. The terminal moraine lies immediately north of this lake. North of Tenino, the moraine is of a character considerably changed from that in the Bald Hill region. It has here become a single massive till ridge on the plain, and surface bowlders are not sufficiently numerous to attract attention. It is two miles wide and 250 feet above its base on both north and south sides, the highest point examined reaching 550 feet A.T. On each side, it is flanked by an outwash gravel plain bearing peculiar tumuli. The till mass appears to cover several rock knobs and hills, whose existence may have in some measure determined its location and relief. Both east and west of Tenino, quarries in sandstone have been opened on the slopes which rise farther to the north in the moraine. The road north from Tenino to Olympia cuts into decayed shale strata *in situ* at the summit of its grade across the moraine at about one-half the maximum height of the moraine, and at McIntosh rock outcrops occur on the south base of the moraine.

The hills which rise south of Tenino were carefully examined for drift materials. Three distinct terraces of outwash gravel were found, occasionally showing forests beds descending southward toward the Skookum Chuck. The highest gravel lies 360 feet A.T., and above it drift abruptly ceases.

Flanking the frontal margin of the moraine from Tenino west to Black River is an extensive area of outwash gravel, known as the Grand Mound Prairie. It is entirely barren of forest growth and almost useless for any agricultural purpose because of the coarseness and depth of the gravel. At the contact between moraine and outwash examined no apron structure was found. The gravel plain apparently was built by outwash occurring through breaks in the moraine ridge and not by outflow from the ice edge when standing at its maximum limit.

The whole region south of Puget Sound bears much outwash, both

extra-morainic in position and lying back of the ice limit. These areas are all alike in being natural prairies because of the coarseness of the soil and in bearing a surface deposit of black silt of variable thickness. Many of them exhibit a very interesting surficial development into mounds of fairly uniform size and distribution composed of mingled gravel and silt without stratification. Where typically developed, they resemble a field of closely spaced haycocks. Their origin is not clear. Grand Mound Prairie bears these tumuli over a considerable portion of its extent.

Some distance back from the frontal edge of the terminal moraine between Tenino and Little Rock a new railroad grade affords frequent exposures of the Vashon till overlying drift of much greater age and with bedrock often appearing beneath the drift. Hills of the moraine occur on the east side of Black River a mile south of Little Rock, while across the river on the west, a morainic tract of low relief occurs about a mile wide. In this tract is a splendid exposure of Vashon till highly charged with rounded gravel which is doubtless overridden and incorporated outwash material.

Mima Prairie, southwest of Little Rock, is another part of the outwash gravel plain and forms a sharp re-entrant angle in the surface till exposures, though hardly recording such an ice margin form, the till being probably buried beneath this northward angle of the outwash. Between Mima Prairie and the Black Hills, unweathered Vashon till was observed in a gravel pit with a thickness of three feet overlying a very red and decayed till of undetermined depth. Small pebbles of the latter were often easily cut in two with a knife, while those of the overlying Vashon were firm and unweathered.

No drift is found back in the Black Hills except a sprinkling of pebbles in re-arranged residual material on the slopes which face the broad drift plain eastward. The region is exceedingly difficult to examine, the forest being almost impassable. Entrance into the hill region is gained on a logging railroad and on various trails. One road crosses near the northern part of the hills, passing west from Olympia close to Summit Lake. Drift has been found near this lake on the north slope of the hills up to an altitude of 1,460

feet, falling short a few tens of feet of reaching the summit. No till has been found in the valleys of any of the south-flowing streams of the region.

Summit Lake lies in the upper part of a preglacial valley, the lower southern portion of which bears a drift filling. The ice sheet certainly overrode the divide at the northeast of Summit Lake but it brought over no drift. Farther south, however, the valley opens into a larger one trending east and west, and from both directions in this, till was carried into the Black Hills. Again the relation of agriculture to the drift is illustrated in the occurrence of several small farms on the broadened valley floor produced by drift filling while elsewhere the region is covered with primeval forest or the waste of logged-off land.

At least two distinct valley trains cross the western part of the Black Hills to the Chehalis River, the larger of these being a filling so complete that several rock hills rise like nunataks from the gravel plain. This enters the Chehalis valley at Elma, in the vicinity of which it is deeply incised by creeks, its structure being thus plainly revealed. A feature of the gravel is the prevailing reddish color, fairly uniform throughout the mass. The freshness of the pebbles and the youthfulness of drainage on the plain, however, show this staining to be due to some other cause than age. The Vashon till near the head of this valley train is also deeply red while its pebbles are fresh. The explanation is thought to be found in the incorporation of residual material from the basalt rocks of the Black Hills.

The country lying between these hills and the Olympic Mountains is practically a great gravelly waste. The forest is thin over large areas and open prairies occur in the region south of Hood's Canal. The moraine hills when found are often largely buried in outwash and the extreme limit of the ice as mapped is consequently only approximate, being based on the occurrence of till outcrops above the gravel plain. No definite ridging tangential to the ice margin was observed in the till hills seen, though their occurrence forms a zone a few miles wide, whose outer margin has been indicated as the limit of Puget Sound ice to the west.

The character of the till, where exposed in railroad cuts and

stream valleys, appears identical with that shown in the vicinity of Seattle, on the slope of the Bald Hills, and in other widely separated regions. The matrix is somewhat sandy, the pebbles and bowlders are rounded, and large erratics are rare. Granite of various kinds is abundant, though granite is not known in the neighboring Olympics. The till is seen to overlie fresh gravel in a few sections with a thickness of about three feet. Its altitude probably does not reach much above 450 feet A.T.

Lake Nahwatzel lies in a decidedly morainic area, the monotonous gravel plain giving place to rolling hills of till which rise 50 feet above the lake surface. These morainic hills lie probably over the lowest preglacial rock surface between the Black Hills uplift and the Olympic foothills, and in such a situation we may find an explanation of the more pronounced morainic expression.

The till along the margin from Matlock to the Black Hills often shows a large proportion of deep red clayey material intermingled with fresh pebbles. The presence of such material, doubtless from the incorporation of the residual soil of basalt of which there are frequent outcrops, is to be expected near the ice margin providing the ice was overriding a region previously unglaciated.

The approximate moraine course from Matlock northward bends abruptly back toward Hood's Canal, the greater length of which is closely bordered by the Olympic Mountains on the west. The extent to which Puget Sound drift penetrated into the valleys of these mountains is known in but one case, that of the Skokomish River. Rock along this stream's course is practically absent below Lake Cushman, while the mountain walls rise almost from the lake shores on the upstream side.

Puget Sound drift of Vashon age composes an extensive plateau 400–800 feet above Hood's Canal, extending back from Lilliwaup Creek directly west to Lake Cushman and also southward to the broad, pre-Vashon lower Skokomish valley. One large rock hill rises through this till plateau just south of the Lilliwaup, otherwise the surface is of rolling ground moraine with occasional shallow kettles. Across the Skokomish to the west are foothills with little or no drift. To the south of the great bend of this stream, extensive

outwash gravels begin, continuing to Shelton in one direction and across the Puget Sound divide to the Satsop in another. In this latter direction, the outwash largely buries the moraine near Matlock and becomes extra-morainic in its further extent.

On the east side of Lake Cushman, the till plateau becomes ridged and kettley, though a dense forest prevents satisfactory examination. The morainic character is best seen along the trail from the head of the lake to Lilliwaup. The material on the lakeward face of these ridged drift hills nowhere contains granite, though two very careful examinations were made. In but one place are granite pebbles found on the shore or in the immediate vicinity of the lake, this being in the bed and delta of the largest stream entering the lake from the northeast. Yet a mile back from the lake, to the east, granite bowlders are found lying on the surface, becoming very numerous two or three miles farther east.

The limit of the Puget Sound drift is thus seen to lie close to the lower end of Lake Cushman, the basin of which is caused by the damming of the Skokomish River valley. The inner slope of the drift dam is probably faced with the terminal deposits of the Skokomish valley glacier, which was unable to advance farther in the face of the overwhelming mass of the Vashon glacier. It may have earlier deployed farther out on the plain, but if so the deposits are buried beneath the Vashon drift. That a valley glacier must have existed back of the drift dam of Lake Cushman when the Puget Sound ice was at its maximum is evident, else the lake basin would have filled with outwash. A till with very angular débris, none characteristic of Puget Sound drift, lies back of the drift dam on the slope of Mt. Ellinor, immediately north of the lake. It is estimated to reach 500 feet higher than the lake surface.

As shown on the map, the western margin of the Puget Sound glacier north of Lake Cushman is approximate only. The mountains rise close to Hood's Canal throughout the remaining distance included in the accompanying map, and in all probability there existed no embayment of Puget Sound ice in the other river valleys entering the Canal comparable to that of the Skokomish valley.

IV. GENERAL CONSIDERATIONS

Considering the altitudes of the terminal moraine only where facing driftless country to the south, its crest is found to have no great range in elevation above the sea. On the north slope of the Bald Hills, near the headwaters of the Des Chutes River, the moraine crest is probably nowhere more than 900 feet A.T., though erratics occur 320 feet higher. Near Tenino, where the moraine is most typically developed on the plain, the crest is probably less than 600 feet in altitude. The existence of buried rock hills in the moraine in this region has been noted. At Little Rock, the moraine surface on the west side of Black River can hardly have been lowered by erosion of escaping glacial water or subsequent stream action, and is approximately 150 feet above the sea, the lowest altitude in the moraine. From this altitude is a descending slope southward, on which the ice ceased to advance. The opposing northern flanks of the Black Hills, deeply cut by valleys, did not permit assumption of the moraine form. Drift, however, has its upper limit in the re-entrant angle which they produced, at an altitude of 1,460 feet. The flattened lobe northwest of these hills has its moraine hills about Lake Nahwatzel at 450 feet A.T. Puget Sound and Olympic drift damming Lake Cushman reaches observed heights of 950 feet above the sea.

The data available for an estimate of the thickness of the ice and its frontal slope are meager. Three miles from Little Rock, the glacier left its till at the eastern foot of the Black Hills at an altitude of about 150 feet. From here it is 10 miles north to the upper drift limit near Summit Lake, at 1,460 feet A.T. The slope in this instance is approximately 130 feet per mile. Fifteen miles east of Seattle rises the peak of Mt. Issaquah, about 3,000 feet A.T., whose frost-riven summit bears no residual soil comparable to that found on hills of much the same lava rock beyond the limit of the drift. Scattered erratic pebbles were found on the summit, their number increasing on the lower slopes. With the maximum depth of the Sound near Seattle at 964 feet, we may conclude that in the latitude of Seattle the glacier attained a thickness of 4,000 feet, allowing very little for central surface convexity, which would increase the estimate an unknown amount.

Evidence of the lack of vigorous movement near the frontal margin of the glacier is shown in the occurrence of deeply decayed material overridden by the ice. Shale strata, profoundly decomposed, are exposed east of Little Rock. Though slightly crumpled and in one case bearing an intruded arm of the till, this incoherent and rotted shale has been but little eroded by the ice, though it is two or three miles back from the moraine front. West of Little Rock, where Vashon till is found at its farthest southern extent along the Black Hills, a knob of old red till is exposed beneath it. Depth of weathering and staining are the same on the slopes as on the summit of this knob, hence the inference that no erosion of the projecting softened till was produced by Vashon ice.

The accompanying map indicates only the extra-morainic outwash. Great areas lie within the moraine limits of essentially the same character and age. In the case of all outwash deposits, the discharging water was received by the Chehalis valley largely on the east or west side of the Black Hills. Extensive tracts are rendered as worthless for agriculture by these outwash plains as though in an arid country. For example, the road through the sparse forest extending from Lake Nahwatzel to Shelton crosses but one stream bed and this carries water only during the very rainy winters and no valley has been cut. As already noted, the moraine across the low area between the Black Hills and the Olympic foothills has been partially buried in the flood of gravel and its relief much reduced.

The question of contribution from valley glaciers in the bordering Cascades and Olympics cannot be adequately treated in our present state of knowledge. Valley glaciers in these mountains on the Soundward slopes debouched into a great mass practically filling the depression from rim to rim. That they would perform much erosion under such conditions is not to be expected. Willis has found the till sheet of a Cascade piedmont glacier on the eastern part of the Tacoma quadrangle, a part of which is indicated on the accompanying map. The relative insignificance of the Skokomish glacier whose lower extremity occupied the basin of Lake Cushman has been shown. No evidence has yet been found that tributary glaciers north of these two produced any perceptible

effect on the mass of the course of the great Vashon glacier, whose volume and thickness was of course greater northward.

Definite recessional moraines are yet unknown in the Puget Sound country. Between the terminal moraine and the southern arms of the Sound are occasional moraine hills and ridges which will probably resolve themselves into linear arrangement when carefully studied and will constitute recessional moraine deposits. But in the larger area of longitudinally ridged drift among the arms of the Sound, there is little of morainic origin beyond scattered lodge moraine hillocks in the valleys.

Russell[1] first noted that there are two till sheets in Puget Sound basin, recording two glaciations. Willis[2] has named these the Admiralty and Vashon, with the latter of which we have had to do. The frequently weathered condition of the Admiralty till or of its superposed outwash has been pointed out by Willis as evidence of long exposure before the Vashon glaciation. The freshness and slight erosion of the Vashon till sheet and moraine evince an age comparable to that of the Wisconsin drift.

A notable feature of the Puget Sound glaciation, shown by the failure of constant careful search to find older till beyond the moraine, is that the last glaciation of the region, doubtless Wisconsin in age, was the most extensive. Frequent incorporation of residual soil in the Vashon till is the best evidence which might be secured, in the absence of deep sections, that it overlies areas never previously glaciated.

[1] Bailey Willis, "Drift Phenomena of Puget Sound," *Bull. Geol. Soc. Am.*, IX.

[2] Willis and Smith, "Tacoma Folio No. 54," *U.S. Geol. Survey.*

Editorial

THE SEEDING OF WORLDS

As a sort of initiation stunt precedent to admission into the fraternity of agencies of good and regular standing, every new agent that is brought into view by the ongoings of science is likely to be set to the task of solving some large part of the outstanding puzzles that still vex the wise men of our craft. "Light pressure" is one of the latest novitiates on trial, and has been set to the stunt of seeding the habitable but not inhabited worlds by spores from some previous spore-growing world. The seeding of the first world is mercifully not made a part of the stunt. So too, to help out the novitiate somewhat, the hazards of the cold of space are mitigated by bringing to bear certain novel tenets about endurance of extreme cold, and by cutting the time by the great speed of the trip from world to world under the new pressure. The stunt still remains a stiff one and is interesting, but the fraternity seems to be missing the best part, the getting home to the new world; no doubt because it is so far off.

The start of the spore from the spore-growing planet is not without its little difficulties; for the seed, be it even so light as the airy fluff of the puffball, must yet not only get out to the very top of the air, but it must be pushed off by the pressure of the light at a speed of some 5 or 6 miles a second to be able to get away from the pull of the parent world, if that world be a body like our familiar acquaintance, the earth. A Krakatoan blast, however, can no doubt give the spore a lift, if need be. But the getting away is not the interesting part of the stunt; it is the landing.

If "light pressure" has once pushed the spore out of the clutches of the parent world and got it well under way, all is likely to go well till the bounds of the sun's sphere of control are reached and the border of the domain of the other sun is entered, for that sun is likely to push back as much as the parent sun pushed out. In matters of this sort one sun seems unwilling to be the dumping-

ground of another sun. So now, between the opposing pushes of the rival suns, comes the real trial of skill or luck in landing the spore. If the seed be duly planted, the fraternity door should surely open for the candidate *magna cum laude*.

On leaving the domain of the old sun and entering the field of new suns, care or luck in hitting on a sun that shines less bright than the one that has pushed the spore out is surely needed, or else the back-push of the brighter sun will grow in time to be stronger than the on-push of the old sun and the spore will be stopped or turned aside. If someone churlishly remarks that the seeding of new worlds can thus only go down the scale of solar radiance, let that pass; it is enough to seed at long distance any world.

Hitting upon a sun of duly lesser radiance, the spore must shoot straight for it, quite straight, center to center, for if the backward push of the sun ahead is a little awry at the front, the spore will be pushed aside and out of line, and once off the line it will be turned more and more away and surely go astray. Nor must the chosen sun move out of line while the spore is coming toward it, or else the front push will surely turn the spore away. No sun must be hit upon but one that will stand still, if such there be, while the spore is getting home to the new planet, or, if no sun stands still, a sun must be hit upon that is coming toward or else is going straight away from the advancing seed.

All ill luck in hitting the right path or in hitting on a sun moving straight toward or straight away from the speeding spore once duly escaped, the larger perils are past, but not all; there are perils of side pushes. In hitting upon a star of proper weakness of radiance and coming or going or standing still duly, the spore may chance to pass some brighter star off the line and its side push may turn the spore off its course; or stars may be thicker or brighter on one side or another and the spore be put off its course by their united pushes. Where, then, it may again be churlishly asked, is a spore to go if all the suns push it away? Well, it is not a part of this stunt to chase up lost spores; still, there are "dark lanes" and "coal sacs" and "openings" leading out into room "outside the universe."

Then too there are perils of planets as well as perils of suns.

As the spore pushes down against the radiance of the defendant sun, one of whose planets, near enough to it to keep duly warm, is to be seeded for a new life kingdom, a planet just at the right spot must be hit upon. Luck must here stand the spore in good stead, for the chances are not the best. If the planets of the chosen sun circle round it cross-ways, in any but the minutest degree, they will never be in the center-to-center line of the spore's path, for, as we have seen, the spore must keep true to line or the backward push of the light pressure in front, striking aslant, will turn the spore off. There is a chance indeed that a spore will get down to just the right point and then be turned off just so as to strike a planet that is off line, but it is not a chance to stake much on. To have any fair chance of getting home to a planet while the spore keeps straight on toward the repellent sun, under the superior inertia it got from the sun it left, the planet must circle round the sun in a path that cuts this line.

And then, too, the planet must be there at just the right time. The spore must no doubt cross the spot in the wink of an eye, or less, and the new world must be there on exact time if it is to be seeded. It is not unfair that it should be made to be there on time as its part of the stunt, for the spore has come far to do its part.

Now if all has gone well thus far there is only the landing left. If the spore was pushed out from the old sun too fast, it may plunge so swiftly into the air of the new world as to strike fire and burn or brown itself fatally. But if pushed out just right at the start and pushed back just right on the road, it may land with little more than the speed forced by the pull of the new earth, a matter of a few miles a second, it may be.

When the speed of the spore is stopped and it floats in the outer air of the new earth it may perchance from being too hot come quickly to be too cold and the change from warmth to chill may try its salamandrine powers before it sinks to the warm air low down or to the ground in which it is to grow.

The luck of the spore must stay by it a little farther in its lighting. All may be lost if it falls on polar snow, or mountain peak, or desert plain, or perchance in the ocean midst, if it is not

a salt-water spore. It must fall in a spot where it can grow, where its family, as it comes to have one, may live and multiply and grow into a kingdom, for if it fails in this last, the kingdom will not be won.

The stunt may be perilous; but it is easy to see how easy it is to do if done just right. Light is the great foster-farmer of the earth, the truly great farmer; and we now see how clearly and truly "light pressure" is the long-distance seed-planter of the worlds. T. C. C.

ARTESIAN WATERS OF ARGENTINA

The climate of a part of Argentina is semi-arid, and the geological formations which are regarded as Quaternary and Later Tertiary are, in the western and central districts of the country, saline to a degree which indicates prolonged duration of aridity. The region of the Pampas which covers the province of Buenos Aires and stretches northward west of the Parana does not exhibit this characteristic, having apparently long enjoyed a more humid climate, as it does now. The foothills of the Andes are also well watered. But with the exception of these last-named regions, a great part of the country suffers from lack of good water. This condition may, however, be in some measure relieved by proper development of artesian supplies. Many wells have been sunk already, but without adequate geological investigation. In the Pampas, water is found at a general depth of 20 meters more or less, and is pumped to the surface by windmills. It may be said that the development of the livestock industry of Argentina would be impossible were it not for this supply which comes from eolian, alluvial deposits of Quaternary and Tertiary age. A different geological condition exists from the Rio Colorado southward in what may be best described as northern Patagonia. In that region there are local elevations occupying a middle position between the Atlantic and Pacific, composed of granites and older rocks possibly of Paleozoic age, and rising to altitudes of 300 to 1,000 meters. These mountains are not represented upon any map and their distribution is not known, but they have been described by Moreno and other explorers. Upon their flanks there

is an extensive formation of gray sandstone which attains a thickness of several hundred feet and is very porous. It slopes gently toward the Atlantic and pure water flows from it in outcrops near the coast. The head of water in these strata is unknown. Farther south in Patagonia the central sierra is replaced by plateau country and in Comodoro Rivadavia, in latitude 46 near the coast, wells which were sunk by the government in search of water developed petroleum. There is a large area in this region in which the geologic structure and the possibilities of artesian water need to be developed. In the great plains east of the Andes there are glacial deposits which may furnish superficial supplies like those of the Dakotas, and the marine Tertiary and Mesozoic strata afford conditions not unlike those of southern California. Here as well as in the valleys among the spurs of the Andes from Patagonia to Bolivia the geological structure is complicated and the problem of artesian water is one of peculiar difficulty as well as of great interest.

Our present knowledge of these conditions rests upon reconnaissance work and the stratigraphic and paleontologic observations of the Geological Survey of Argentina. No work based upon topographic maps and systematic structure has as yet been undertaken. The problem is therefore one whose elements are as yet to be developed. The Argentine government is using every means to encourage settlement and development of the rich agricultural regions which lie in the zone of sufficient rainfall east of the Andes, and also the vast grazing district of Patagonia. In order to afford ready communication it is building railroads at great national expense and operating them. The need of pure water for locomotive use as well as for other purposes has thus been made critically evident, and the minister of public works, Señor Ramos Mexia, has adopted a plan for making surveys for the determination of artesian water conditions along the lines of national railways. He contemplates topographical and geological surveys of a character similar to those executed by the United States Geological Survey, from which he derived the initial suggestion. He last summer applied to the United States government for the services of a geologist and such assistants as he might need, and our govern-

ment has responded cordially to that request. Mr. Bailey Willis has accordingly entered into a contract for the term of two years, to execute topographical and geological surveys for the specific purpose of ascertaining artesian water possibilities in those districts which the minister may designate. With him are associated Mr. Chester W. Washburne of the United States Survey, Mr. J. R. Pemberton of Stanford University, and Mr. Wellington D. Jones of the University of Chicago, as geologists, and Mr. C. L. Nelson and Mr. W. B. Lewis as topographers, and the party has recently sailed for Argentina to enter upon the work. While these surveys have a specific purpose, their possibilities of usefulness in developing the natural resources and encouraging settlement in the regions surveyed will not be overlooked, and the work will be founded on those scientific studies upon which alone practical conclusions can safely rest. Thus it is hoped that a definite contribution to knowledge in geography and geology may be made.

It is desirable to point out that the Argentine government has a geological survey which has been in existence since 1903 in its present organization and which dates back half a century as a bureau of mines. It is under the direction of Señor E. M. Hermitte, who is assisted by Messrs. Bodenbender, Keidel, and Schiller, three German geologists who have done excellent stratigraphic and paleontologic work, particularly in districts of the central Argentine Andes. They have unfortunately not been supplied with maps. The established Bureau of Mines, Geology, and Hydrology is under the Minister of Agriculture. The surveys which are about to be made are undertaken by the Minister of Public Works. The two operations are thus officially distinct, but it is hoped and anticipated that they may be mutually helpful.

B. W.

Petrographical Abstracts and Reviews

Edited by ALBERT JOHANNSEN[1]

Benedicks, Carl, and Tenow, Olof. "A Simple Method for Photographing Large Preparations in Polarized Light." *Bull. Geol. Inst. Univ. Upsala*, IX (1910), 21–23.

For the description of the comparatively simple apparatus used, reference must be made to the original paper.

W. T. Schaller

Bowles, Oliver. *Tables for the Determination of Common Rocks.* New York: Van Nostrand, 1910. 16mo, pp. 64+84 advs. 50 cents net.

Cui bono?

Written, as this book is, for "beginners in lithology," it is especially unfortunate that the author's statements are often very misleading. For example, in the chapter on "Rock Classification" the statement is made that "igneous rocks . . . . represent the original solid crust of the earth," and that "sediments . . . . are but modifications, or reconstructed phases, of this primary type." A short chapter on the determination of the rock-forming minerals is followed by 18 pages of tables for the determination of the common rocks. The methods of identification are given in extremely brief form, but would a "beginner," or anyone else, classify andesite, quartz porphyry, felsite, or phonolite as "ashy, and often with a few phenocrysts, mostly cellular"?

The book ends with a ten-page chapter on "Building Stones" and a seven-page glossary. The volume is No. 125 of Van Nostrand's Science Series and is uniform in size and binding with the remainder of the set.

Albert Johannsen

Bowman, H. L., and Clarke, H. E. "On the Structure and Composition of the Chandakapur Meteoric Stone," *Min. Mag.*, XV (1910), 350–76. Pls. 2, and analyses.

A full description, with extensive chemical work, on a large piece of the meteoric stone which fell at or near Chandakapur, India, on June 6,

[1] Authors' abstracts will be welcomed and may be sent to Albert Johannsen, Walker Geological Museum, The University of Chicago, Chicago, Ill.

1838. It is an intermediate chondrite, with olivine and pyroxene as the most important constituents. Metallic iron and nickel form nearly 6 per cent, and combined iron and nickel, 5 per cent.

W. T. SCHALLER

DALE, T. NELSON. "The Cambrian Conglomerate of Ripton in Vermont," *Am. Jour. Sci.*, XXX (1910), 267–70. Figs. 3.

A conglomerate formed of pre-Cambrian pebbles generally held together in a highly metamorphosed "muscovite-quartz schist with more or less magnetite." The pebbles are a beach formation and are of local origin as is shown by their large size and by their similarity to adjacent rocks.

ALBERT JOHANNSEN

DUPARC, WUNDER, AND SABOT. "Les minéraux des pegmatites des environs d'Antsirabé à Madagascar," *Mém. Soc. Phys. et d'Hist. Nat. Genève*, XXXVI (1910), fasc. 3, 283–410.

The geology of Madagascar is briefly described and then, in detail, are described the rocks around Antsirabé. These include basalts, granites, quartz diorites, pegmatites, cipolines, quartzites, and mica schists. The localities of the pegmatites are then given in detail. The pegmatites occur chiefly in the cipoline and are formed principally of microcline and quartz, or plagioclase (near albite) and quartz. Mica, tourmaline, beryl, garnet, and pyroxene are also present.

In the second part of the paper are mineralogical descriptions of microcline, amazonite, lepidolite, lithionite (zinnwaldite), beryl (rose-pink and aquamarine), tourmaline, spodumene, spessartite, garnet, and cordierite from the mica schist of Mount Ibity.

W. T. SCHALLER

GRABHAM, G. W. "An Improved Form of Petrological Microscope; with Some General Notes on the Illumination of Microscopic Objects," *Min. Mag.*, XV (1910), 335–49. Figs. 5; pl. 1.

Suggests several improvements on a Dick microscope, namely, a better adjustment for the condenser system, a triple nose-piece, iris diaphragm, and a slot for introducing screens below the stage. The graduated circle is placed below the ocular. Several other suggested improvements have already been used on other microscopes. Several

pages are devoted to the "Illumination of the Object." An explanation of the "white-line effect" (Becke's line) is given for parallel light where the contact plane of the two minerals in question is at various inclinations.

W. T. SCHALLER

GRAYSON, H. J. "Modern Improvements in Rock Section Cutting Apparatus," *Proc. Roy. Soc. Victoria*, XXIII (1910), 65–81. Pls. 4.

Describes an apparatus, constructed for the University of Melbourne, with which the writer is able to slice, grind, and mount thin sections of about an inch in diameter and of a thickness of less than 0.001 inch, from rocks of the hardness of granite, in not more than ten minutes. Using two cuts with a diamond saw for each slide, the cost per section is about one shilling.

A mechanical device for doing the rough grinding would be an improvement. With a number of laps running simultaneously, the greater length of time required for each section would be no drawback, and there would be a considerable reduction in cost since it would not be necessary to use diamond dust.

ALBERT JOHANNSEN

GROUT, FRANK F. "The Composition of Some Minnesota Rocks and Minerals," *Science*, XXXII (1910), 312–15.

A preliminary statement regarding the composition of certain Minnesota rocks. There are given analyses of seven rocks and fourteen minerals.

Two or three types of granite occur in laccoliths of considerable size in the Keewatin schists and are considered by the author as probably of that age. These granites are intersected by diabase, quartz diabase, and quartz porphyry dikes, and there occur a few masses of gabbro. Most of the Minnesota effusive rocks belong to three types of diabase which, chemically, are classed as Hessose, Bandose, and Auvergnose.

The country rock was tested for copper. The common theory of the origin of the Lake Superior copper deposits is that of lateral secretion from the diabases. In the present tests it was found that copper occurs in all the main types of rock, and, so far as could be judged from the ten samples tested, the fresher the rock, the larger the amount of copper. It varied in amount from 0.029 to 0.012 per cent.

ALBERT JOHANNSEN

HÖGBOM, A. G. "Ueber einen Eisenmeteorit von Muonionalusta im nördlichsten Schweden," *Bull. Geol. Inst. Univ. Upsala*, IX (1910), 229–38. Pl. 1.

This is a description of the first iron meteorite found in Sweden. The essential constituents are the iron-nickel kamazite, taenite, and plessite. Troilite and daubréelite form a minor part. Chemically, the meteorite contains 91 per cent Fe and 8 per cent Ni.

W. T. SCHALLER

DE LAPPARENT, JACQUES. "Les gabbros et diorites de Saint-Quay-Portrieux et leur liaison avec les pegmatites qui les traversent," *Bull. de la Soc. Française de Minéralogie*, XXXIII (1910), 254–70.

Near Saint-Quay-Portrieux on the coast of Brittany, intrusive in mica schists, there is a mass of rather coarse hypersthene-gabbro with a periphery of dioritic facies. Both gabbro and diorite contain inclusions of a finer-grained hypersthene-bearing rock with the structure of beerbachite. These rocks are cut by dikes of aplite essentially composed of labradorite and quartz. The diorite and the marginal, but not the central, part of the gabbro are cut also by small dikes of pegmatite composed essentially of microcline, albite, quartz, and a little biotite, with local muscovite and tourmaline. The albite has crystallized before the microcline.

The principal types are represented by five analyses.

The microscope shows the hypersthene of the gabbro in process of replacement by a mixture of biotite and quartz, and the augite more or less uralitized. In the peripheral "diorite" both alterations are much more advanced; the augite is almost completely uralitized, and the hypersthene wholly replaced by biotite and quartz. The author ascribes these changes to the agency of the pegmatite and believes them to have been effected before the gabbro was fully consolidated. He considers for reasons not fully stated that the first phase was the production of soda-lime feldspar by the reaction with the femic magma of siliceous alkaline vapors, rich at first in soda. He supposes the vapors subsequently to have become more abundant and richer in potash, water, and boric acid. The quartz and biotite, it is pointed out, would be formed by combination of the constituents of hypersthene with those of potash-feldspar; there is evidence that this reaction took place in the central gabbro before the hypersthene was completely crystallized, and in the

peripheral "diorite" even before that mineral was individualized. The transformation of augite to amphibole, accompanied by crystallization of quartz, is considered to have been the final reaction, effected mainly by the water and boric acid in which the vapors became relatively richer as the consolidation of alkalies and silica progressed.

M. de Lapparent believes that the action of the kind here described is common, and especially, that it has occurred in certain American rocks.

F. C. CALKINS

MICHEL-LÉVY, ALBERT. "Les terrains primaires du Morvan et de la Loire," chap. v, "Etude pétrographique et chimique des roches éruptives du faisceau synclinal du Morvan." *Bulletin des Services de la Carte Géologique de la France*, XVIII (1908), 209–68.

The area described is part of the central plateau of France, made classic by the thorough studies of the elder Michel-Lévy and others. Its rocks furnished the basis for some important principles of the science, and some of them are illustrated in the beautiful plates that accompany the "Minéralogie Micrographique." A historical summary and bibliography relating to these early researches is given in the present work. The petrographic descriptions in this work are brief; its principal contribution is a series of chemical analyses, twenty-five in number, which are used to show the position of each rock in the American quantitative classification and in that of Michel-Lévy.

The principal deep-seated rock is a coarsely porphyritic granite (alaskose) with potash distinctly more abundant than soda. The phenocrysts of potash feldspar are the last constituents to crystallize. This rock passes into microgranite and "microgranulite." Associated diorite (hessose) and amphibolitic porphyries (andose and tonalose) are said to have been formed by digestion of calcareous sediments in the granite. No full argument in support of this assertion is made, the author evidently considering that previous work by Michel-Lévy and Lacroix has established the frequent occurrence of this type of endomorphism.

The exomorphic action of the granite has affected limestones, shales, sandstones, and conglomerates. The most interesting result of the metamorphism has been the introduction of albite and orthoclase in all these rocks, especially in close proximity to contacts, by "alkaline fumaroles" from the magma.

The volcanic rocks—of Paleozoic age—comprise: (1) Upper Devo-

nian albitophyres, in the form of breccia and tuffs, with phenocrysts of albite, orthoclase, microperthite, and rarely of brown hornblende, in a groundmass of albite microlites. In the quantitative system these belong to dacose, andose, and subrang 5 of dacose, not named nor even represented by analyses when that system was published. (2) Carboniferous orthophyres, also in the form of tuffs and breccias. The phenocrysts are of orthoclase, albite, and in some cases anorthoclase; the groundmasses where crystalline are of orthoclase microlites and poikilitic quartz; some are glassy and perlitic. They belong to alaskose, liparose, and the unnamed subrang I (perpotassic) of alaskose. (3) "Microgranulitic tuffs," consisting of fragments of andesine, bipyramidal quartz, and biotite in a chalcedonic cement. These are water laid and apparently not of purely volcanic material. They belong to toscanose and are more limy than the albitophyres. (4) "Microgranulites." Some of the rocks thus designated are hypabyssal, others, passing into "porphyre pétrosilicieux," are thick, devitrified rhyolitic flows. An analysis of the hypabyssal rock is that of a toscanose, while the two specimens analyzed of the extrusive rock are alaskose and liparose. (5) Lamprophyres. These also occur partly as thin dikes and partly as flows. The dike rocks have phenocrysts of biotite and pyroxene in a groundmass of orthoclase, plagioclase, and biotite; the lavas have phenocrysts of olivine, augite, and sometimes hypersthene, in a groundmass of plagioclase, orthoclase, and sometimes biotite. In the quantitative classification, they are harzose, shoshonose, and auruncose. Chemically both extrusive and intrusive "lamprophyres" are characterized by richness in potash, resembling in this respect the porphyritic granite from which they are supposed to be differentiates.

The author summarizes the chemical data by estimating the average composition of each group of rocks and of all the rocks together excepting the diorites, albitophyres, and granulites. With these exceptions, all are markedly consanguineous, and the general average composition has in the scheme of Michel-Lévy the same "magmatic parameters" as the granite supposed to be the "mother-rock."

The albitophyres, by their richness in soda, are in remarkable contrast to the other rocks, in which dominance of potash is general. It is a striking circumstance that names are wanting in our quantitative classification for two of the albitophyres because of their unusual richness in soda, and for two other rocks—an orthophyre and a lamprophyre—because of their unusual richness in potash.

F. C. CALKINS

NORDENSKJÖLD, IVAR. "Der Pegmatit von Ytterby." *Bull. Geol. Inst. Univ. Upsala*, IX (1910), 183–228.

Numerous lenses of pegmatite occur at Ytterby on Resarö Island, about 20 km. E.N.E. of Stockholm. Some of the pegmatites are found between diorite and gneiss, and others occur in hornblende gneiss. A zonal structure is noticeable, the pegmatites being finest grained near the contact. Large masses of pure red potash feldspar (microcline perthite), white plagioclase (oligoclase), and massive quartz are found in the center of the lenses. The potash feldspar is especially valuable and the minerals are mined and used in the manufacture of porcelain. Graphic granite is also abundant. Of the micas, a dark biotite is more common than muscovite. It is often chloritized and it is with this altered mica that the rare minerals fergusonite, gadolinite, etc., are found. The descriptions of the rare earth minerals, largely historical, include also yttrotantalite, allanite, xenotime, and altered zircon.

W. T. SCHALLER

RASTALL, R. H. "The Skiddaw Granite and Its Metamorphism." *Quart. Jour. Geol. Soc.* (London), LXVI (1910), 116–41. Map.

A study of the alteration produced in the sedimentary rocks of the Skiddavian Series by the intrusion of an alkali granite commonly known as the Skiddaw granite. The metamorphism extends over a considerable area, although the outcrops of granite are limited to three of rather small extent which the author supposes to be part of a large mass continuous beneath the surface. From the repetition of the same sequence of rock-types in reverse order, it appears that the structure of the region is that of a complicated anticline or syncline, the former being most probable. The position of the granite mass suggests that it was intruded along the main axis of this anticlinorium, and the author believes its injection closely followed or even accompanied the folding. If this is true, here is an example of a direct relation between intrusion and folding. The chief minerals produced by the metamorphism were cordierite, andalusite, biotite, and muscovite, with garnet and staurolite near the granite contact. The absence of cyanite and sillimanite indicates that the rocks were never subjected to a very high temperature, and all the evidence points to the maintenance of a moderate temperature for a long period of time, such as would result from the intrusion, under a thick cover, of an igneous mass not very highly heated.

ALBERT JOHANNSEN

SCHALLER, W. T. "Axinit von Californien," *Zeitschr. Kryst.*, XLVIII (1910), 148.

A chemical and crystallographic description. The conclusion is reached that axinite is composed of the two isomorphous minerals, ferroaxinite, $Al_2B\ H\ Ca_2\ Fe\ Si_4\ O_{16}$, and manganoaxinite, $Al_2\ B\ H\ Ca_2\ Mn\ Si_4\ O_{16}$.

AUTHOR'S ABSTRACT

SMITH, G. F. HERBERT. "A Camera-lucida Attachment for the Goniometer," *Min. Mag.*, XV (1910), 388–89. Fig. 1.

The camera lucida is used for the representation of "light figures" on imperfect crystals with rounded or striated faces, and for the delineation of small crystals.

W. T. SCHALLER

WINCHELL, ALEXANDER N. "Use of 'Ophitic' and Related Terms in Petrography," *Bull. Geol. Soc. America*, XX (1910), 661–67.

A history of the term ophitic which was introduced in the literature by Michel-Lévy in 1877. Originally defined as a texture characterized by feldspars, peculiarly grouped, inclosing more recent diallage or augite, it is at the present time used either in the original sense or applied only to those textures in which the feldspar is inclosed by large anhedra of pyroxene.

The writer believes the term should be applied to all rocks having plagioclase in lath-shaped crystals which were formed before the ferromagnesian constituents, and suggests the term "poikilophitic" for that texture which is at once ophitic and poikilitic.

Alfred C. Lane, "Winchell on Ophitic Texture," *Science*, XXXII (1910), 513, says: "It seems to me that . . . . a pyroxenic matrix is an essential part of the idea of the ophites. I am, however, quite willing to give up the idea that the augite must necessarily be altogether in larger grains than the feldspar."

ALBERT JOHANNSEN

Reviews

Die Weltkarten-Konferenz in London im November, 1909. By Albrecht Penck. *Zeitschrift der Gesellschaft für Erdkunde.* Berlin, 1910. Pp. 114–27.

This paper states briefly what was done at the international conference held in London in November, 1909, looking toward a map of the world on a uniform scale of 1:1,000,000. Starting with the inception of the idea at the Bern meeting of the International Geographic Congress in 1892, past efforts which have led to the present stage are reviewed. The main features of the resolutions adopted by the London Conference were:

That all nations participate in a world map of 1:1,000,000 scale with uniform symbols; that the size of the sheets be uniform; that each sheet cover 4 degrees of latitude and 6 degrees of longitude (except that north of 60° N. lat. and south of 60° S. lat. two or more sheets of the same zone may be united); that each sheet have an international designation, as North B 12; that the latitude of the sheets be represented on each side of the equator to latitude 88° by the letters A to V, and distinguished as "North" or "South"; that each polar chart be designated Z; that the longitude in units of 6° be represented by the numbers from 1 to 60, the count beginning 180° from Greenwich and proceeding from west to east; that in projection, the meridians be straight lines, and the parallels be arcs of which the middle points lie on the prolongation of the middle meridian; that the elevation of the land be represented by a color scale using 100-meter contour division lines for regions of ordinary relief.

In addition to these leading features the recommendations treat of a great many details upon which decisions were necessary in order to secure uniformity of results in the completed map.

While further consideration and conference will be necessary to determine who shall make the different maps, this conference has prepared the way for the adoption at an early date of a common plan of operations. This important enterprise now seems to be fully under way.

R. T. C.

"Prospecting in the North." By HORACE V. WINCHELL. *The Mining Magazine*, Vol. III, No. 6, p. 436. December, 1910.

The writer compares the sulphide ore deposits of the western part of the United States and Mexico with those of British Columbia and Alaska and notes the differences in the operations of the processes of superficial alteration and secondary enrichment in the different latitudes. In the more northern deposits the metals have not migrated in cold solutions so extensively, because the colder climatic conditions are less favorable. Further, the secondary ores, where found, have generally been planed off by ice erosion.

Since glacial times, at some places, a kind of secondary sulphide enrichment has taken place at the very surface, but generally this amounts to little more than a veneer or varnish on the lower-grade material. His conclusions, applied to deposits of sulphide ores of copper, silver, lead, and to some extent, of gold, are: "(1) Boreal regions seldom contain rich and extensive deposits of secondary ore. (2) The surface appearance is often deceptive, and if the ore is high grade, sudden decrease in value may be expected at limited depth. (3) Where large deposits of *primary ore* are found in glaciated regions, these are likely to extend downward." In the temperate zone, "(1) Deep superficial alteration and complete oxidation of vein-matter is a common phenomenon in warm countries and is indicative of good ore below; (2) In general, ore deposits are more abundant in the warm and temperate zones; and (3) They are not so likely to terminate suddenly or change rapidly in depth."

W. H. E.

Geological and Archaeological Notes on Orangia. By J. P. JOHNSON. London: Longmans, Green & Co., 1910. Pp. 99.

This volume contains chapters on Stratigraphy, Kimberlite Dikes and Pipes, Diamond Mines, and Superficial Deposits and Pans.

Almost the whole surface is made up of nearly horizontal beds belonging to the Karoo System, with comparatively small outcrops of older formations along the Vaal River. In the area best exposed these older beds dip away from a central core of granite and are overlain unconformably by the Karoo.

The lowest of the Karoo beds is the Dwyka series, which is described as a band of bowlder shale. The underlying rocks wherever exposed are polished and present the characteristic contours of a glaciated country.

The evidence of the striations indicates a general movement of the ice from northeast to southwest. The Ecca or Beaufort series, consisting of fifteen hundred feet of sandstone and shale, occupies most of the surface, while the Stormberg series is found along the eastern border.

The whole area of Orangia has been intruded by a network of basic dikes and sills of nearly the same composition, and at a later date by the veinlike pipes and dikes of the diamond-bearing rock. This rock, which is known as Kimberlite, has a wide distribution in Orangia, filling both narrow fissures and vents or pipes. Its nature is as yet imperfectly known, some occurrences giving the impression of a consolidated igneous rock, others being apparently purely fragmental. The author thinks that the typical fissure Kimberlite is a magmatic intrusion, and that the pipes were originally filled, perhaps on more than one occasion, with a magma, which, except near the depth of origin, must have had a very low temperature for an igneous extrusion and which, after solidification, was smashed up by frequently repeated explosions.

E. R. L.

The Slates of Arkansas. By A. H. PURDUE, with a Bibliography of the Geology of Arkansas by J. C. BRANNER. Geological Survey of Arkansas, 1909. Pp. 164.

The part of this volume which is of greatest general interest is chap. iii, which deals with the geology of the slate area. This area includes the part of the Ouachita Mountains from Little Rock westward for about one hundred miles. The sedimentary rocks of known age are of Ordovician and Carboniferous (Pennsylvanian) age, with rocks of unknown age both above and below the Ordovician.

Above the rocks of known Ordovician age is a group of three formations of which the well-known Arkansas novaculite is the middle member. In a former publication of the Survey these were all classed as Ordovician, but the author finds no proof of this and thinks that they may be Ordovician, Silurian, or Carboniferous.

The region is one of intense folding, and thrust faulting is quite common.

E. R. L.

Geological Survey of Georgia. Bull. No. 23. "Mineral Resources." By S. W. MCCALLIE, State Geologist. Pp. 208.

The introductory chapter on the geology of the state is brief and presents no new facts. The descriptions of the mineral deposits are arranged alphabetically, the general distribution, the mode of occur-

rence, the history of development and values being treated for each type of deposit. In most cases no attempt is made to inquire into the genesis of the deposits.

In a work of this nature whose value is chiefly statistical one would expect a general summary and table showing the relative importance and value of the various deposits, but none is found in this volume. Of the ores of the state, those of iron are by far the most important. In 1907 they were mined to the value of over $800,000. E. R. L.

The Mining Industry in North Carolina during 1907 with Special Report on the Mineral Waters. By JOSEPH HYDE PRATT. North Carolina Geological and Economic Survey, Economic Paper No. 15. Pp. 176.

The most important part of this paper is a report on the Gold Hill Copper District by F. B. Laney (pp. 20–55). This district is located in the south-central part of the state just west of the Yadkin River. The rocks are slates and igneous rocks of various kinds, and of different periods of intrusion. The ores are (1) auriferous pyrite and chalcopyrite in a quartz gangue and (2) slightly auriferous bornite and chalcocite in a quartz epidote gangue. No attempt is made to correlate the period or periods of ore deposition with a period of igneous activity or to determine the age of the ores.

The remainder of the paper is chiefly statistical.

E. R. L.

Paleontology of the Coalinga District, Fresno and Kings Counties, California. By RALPH ARNOLD (U.S. Geol. Surv. Bull. 396). Pp. 101 and plates 30.

The district forms a strip roughly fifty miles long by fifteen miles wide along the border between the Coast ranges and the San Joaquin valley. The eastern slope of the mountains is formed by a great thickness of strata dipping toward the valley, successively younger formations being exposed to the east. The rocks of the district range in age from the Franciscan formation, which is probably Jurassic, to rocks of recent age, with an unconformity at the base of almost every formation. A description of the formations with faunal lists is followed by description of forms from the Tejon formation (Eocene), the Vaqueros, the Jacalitos, and the Etchegoin formations (Miocene), and the Tulare formation (Freshwater Pliocene).

E. R. L.